Miscellaneous Paper EL-93-21
October 1993

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US Army Corps of Engineers
Waterways Experiment Station

Water Quality Studies: Hartwell Lake 1992 Summary Report

by *Cynthia J. Huffstetler*
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Prepared for U.S. Army Engineer District, Savannah

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Prepared for U.S. Army Engineer District, Savannah
Savannah, GA 31402-0889

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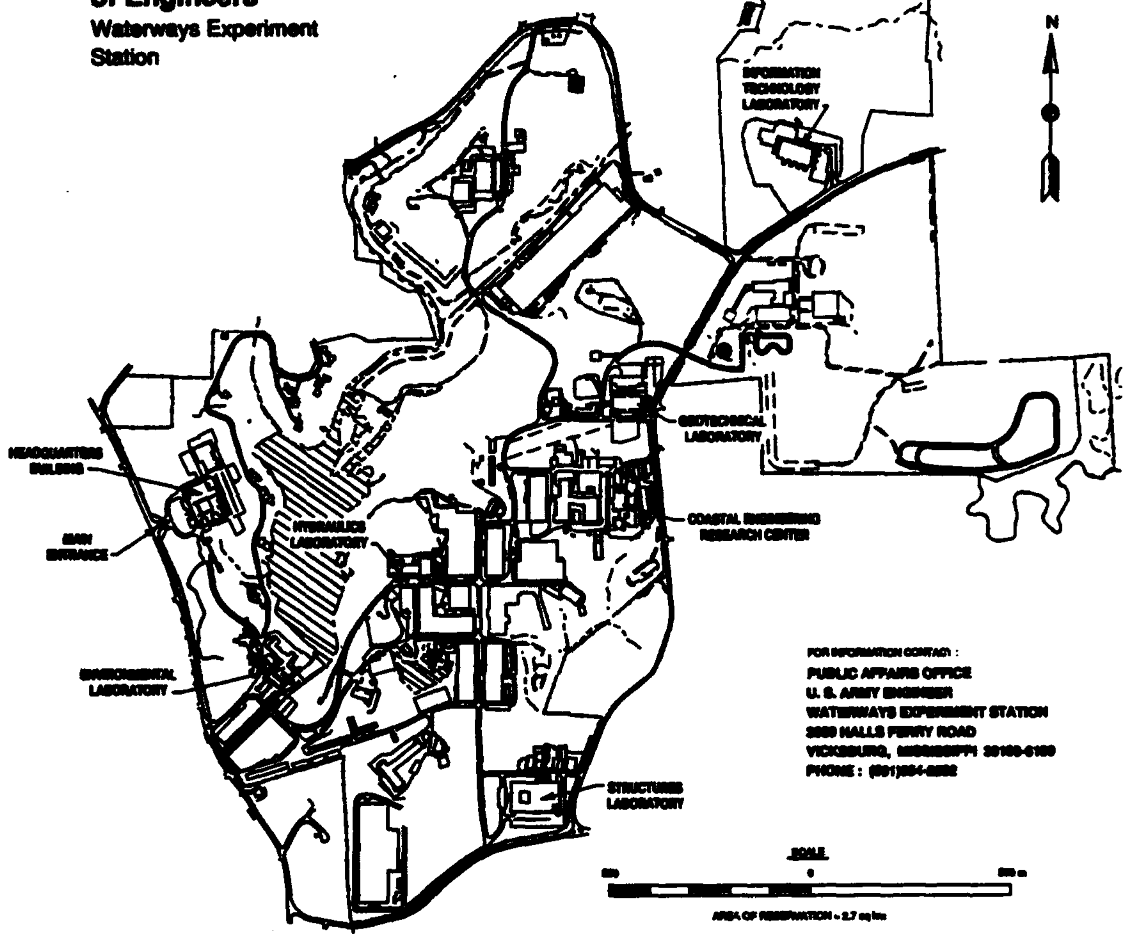

Waterways Experiment Station Cataloging-in-Publication Data

Huffstetler, Cynthia J.
Water quality studies : Hartwell Lake 1992 summary report / by William E. Jabour, Joe H. Carroll ; prepared for U.S. Army Engineer District, Savannah.
57 p. : ill. ; 28 cm. — (Miscellaneous paper ; EL-93-21)
Includes bibliographical references.
1. Water quality management — Hartwell Lake (S.C. and Ga.) — Environmental aspects. 2. Eutrophication. 3. Hartwell Lake (S.C. and Ga.) 4. Limnology. I. Carroll, Joe H. II. Jabour, William E. III. United States. Army. Corps of Engineers. Savannah District. IV. U.S. Army Engineer Waterways Experiment Station. V. Title. VI. Series: Miscellaneous paper (U.S. Army Engineer Waterways Experiment Station) ; EL-93-21.
TA7 W34m no.EL-93-21

Contents

Preface

A comprehensive water quality study at Hartwell Lake was initiated in 1992 as a cooperative effort by the U.S. Army Engineer District, Savannah (SAS), and the U.S. Army Engineer Waterways Experiment Station (WES). This report documents the finding and results of a comprehensive water quality study at Hartwell Lake and covers the period January through December 1992 and is the second annual report documenting findings and results.

The principal investigators for this project were Dr. Robert H. Kennedy and Mr. Joe H. Carroll, Ecosystem Processes and Effects Branch (EPEB), Environmental Laboratory (EL), WES. This report was prepared by Ms. Cynthia J. Huffstetler, AScI Corporation, McClean, VA, and Messrs. Joe H. Carroll and William E. Jabour, EPEB. Field and technical support were provided by the following personnel: Dr. John J. Hains and Mr. William E. Jabour, EPEB; and Messrs. Michael C. Vorwerk and Ryan L. Bass, Dr. Edward E. Robertson, and Ms. Kimberly O. Johnson, AScI.

Additional assistance was provided by Messrs. Steve Mason and Kenneth Bedenbaugh, SAS, under the supervision of Mr. Dick Austin, SAS, and Mr. C. Michael Alexander, SAS, under the supervision of Mr. Bob Bain, SAS. Technical reviews of this report were provided by Drs. Kennedy and Hains and Mr. Steve Ashby, EPEB.

This investigation was performed under the supervision of Richard E. Price, Acting Chief, EPEB; Mr. Donald L. Robey, Chief, Environmental Processes and Effects Division; and Dr. John Harrison, Director, EL.

At the time of the publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

This report should be cited as:

Huffstetler, C. J., Carroll, J. H., and Jabour, W. E. (1993). "Water quality studies: Hartwell Lake 1992 summary report," Miscellaneous Paper EL-93-21, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Introduction

Hartwell Lake is a 22,400 ha impoundment on the Savannah River and provides hydroelectric power, flood control, water supply, and recreational opportunities. In 1991, water quality concerns, particularly those factors related to the entrainment of blueback herring in the deep, near-dam waters, were addressed in the planning and execution of a comprehensive sampling regime on Hartwell Lake. The study was later extended to include 1992. The primary objectives of this investigation were to:

(1) Describe longitudinal water quality trends from the forebay region into the upper Seneca and Tugaloo River tributary embayments during both stratified and mixed periods.

(2) Compare and contrast temporal water quality trends at near-dam stations and those in upstream embayments during a one year period encompassing both stratified and mixed periods.

(3) Monitor release water quality in the Richard B. Russell Lake headwaters through continuous remote sampling in the Hartwell Dam tailrace.

Study Site Description

Hartwell Lake was completed by the U.S. Army Corps of Engineers (CE) in 1963 as part of a comprehensive water resource development plan for the Savannah River basin. Located on the border of Georgia and South Carolina, Hartwell Lake is a multi-purpose project attracting more than twelve million visitors annually, making it one of the most popular CE impoundments in the nation. The lake has a surface area of nearly 22,400 ha, a shoreline of 1530 km, and receives inflows from two major rivers, the Seneca and Tugaloo Rivers, which join to form the Savannah River at their conjunction approximately 11 km upstream of Hartwell Dam. The lake is located downstream of Lake Keowee on the Seneca River and immediately upstream of Richard B. Russell Lake on the Savannah River. The project operates at a power pool elevation of 201 m NGVD, with mean depth and maximum depth of 14 m and 55 m, respectively, and has a fluctuation limit of 2.6 m. The storage ratio or residence time, is 0.83 years. Hartwell Dam is an earth and concrete structure, completed in 1961, which spans approximately 5400 m across the Savannah River. The concrete section is 570 m in length and rises to 61 m above the riverbed. The powerhouse contains four 66-MW generators and one 80-MW generator, which produce an annual average of 453,000 megawatt-hours of electricity. The average outflow from Hartwell Dam in 1992 was 5998 cfs. Generation of power is conducted on a schedule dependent on area requirements and usage.

Materials and Methods

Regular in-situ sampling was conducted monthly throughout the year with the exception of February, November and December. Measurements of tem_ erature, dissolved oxygen, pH, and conductivity were used to describe temporal and spatial patterns of water quality within the main stem and the two major tributaries on Hartwell Lake. Spatial and temporal trends in chemical parameters were documented during July and October. Sampling routines coincided with the mid-summer stratified and fall mixing periods. Water samples were collected at fourteen selected stations in Hartwell Lake and tailrace (Figure 1) and analyzed at the U.S. Army Engineer Waterways Experiment Station (WES) Trotters Shoals Limnological Research Facility (TSLRF). Chemical analyses for nutrients, organic carbon, turbidity, and alkalinity were conducted. A total of fifteen water quality variables were monitored during the 1992 study (Table 1).

Routine water quality monitoring was conducted in-situ using a Hydrolab Surveyor II (Hydrolab Corporation, Austin, TX). Temperature, dissolved oxygen, pH, and specific conductance were calibrated against known standards before each sampling trip. Sample collection for analysis of chemical variables was done using a diaphragm pump and vinyl-lined garden hose. Samples were taken from selected depths, based on seasonal thermal stratification, and included the surface, bottom of the thermocline, and bottom waters of each lake station. Pumped samples were obtained by lowering the sampling hose to the desired depth, allowing sufficient time for the hose to clear by pumping a volume of water approximately equivalent to two or three times the volume of the hose, and then retaining the necessary volume of water for the samples. Outflow samples were collected in a grab fashion with a polyethylene bucket. Samples were iced and transported in coolers from the lake to the laboratory site. Standard methods (U.S. Environmental Protection Agency 1979, American Public Health Association 1985) were used for laboratory analyses of water samples.

Hartwell Lake tailwater in situ data (temperature, dissolved oxygen, pH, and conductivity) were collected and recorded hourly at station 200 with a Schneider Water Quality Monitor, (Model RM25, Schneider Instrument Company, Madeira, Cincinnati, OH). This unit was calibrated regularly during the stratified period using known standards.

Results and Discussions

Precipitation, pool elevation, mean daily inflow and mean daily outflow for the period 1990-1992 are shown in Figure 2. Precipitation varied considerably throughout the year, measuring 2.71 inches and 3.63 inches in July and October of 1992, respectively, as compared to 5.03 and 0.40 inches during the same period in 1991. Chemical sampling trips coincided with these periods of low precipitation. Increased precipitation in the early months of 1992 led to increased pool elevations by March that were consistently maintained throughout the year through controlled releases. Precipitation in the fall was considerably above normal and measured 10.21 inches and 6.44 inches in November and December, respectively, as compared to normal levels of 4.13 and 4.54 inches in November and December. Outflows and inflows were slightly higher in the early months of 1992 as compared to 1991, but significantly higher in November and December of 1992, as a result of the increased levels of precipitation. As in the previous year, increased elevation and more consistent release levels significantly altered water quality conditions in the two major embayments of Hartwell Lake.

Spatial and seasonal thermal patterns for Hartwell Lake are presented in Figures 3 and 4. Stratification was present from Hartwell Dam to the headwaters of the Seneca and Tugaloo River embayments from May through mid-October. Variations in monthly temperatures at Station 210, located in the Hartwell Dam forebay, illustrate the onset of stratification in the main body of the lake (Figure 5). The beginning of lake-wide stratification was observed during early March, and was well-defined by mid-April. Throughout the summer stratified period the thermocline remained between 10 and 18 meters lakewide. Temperatures in the epilimnion ranged between 24 and 30 °C, while hypolimnetic temperatures ranged from 12 to 20 °C during the stratified period. The deepening of the thermocline reflected increased release rates of cooler hypolimnetic waters during the summer months. Normal seasonal cooling, which began in early September and continued into October, decreased surface water temperatures, thereby lessening thermal gradients. Continued cooling and fall mixing resulted in near-isothermal conditions lakewide by November.

Temporal and spatial gradients in dissolved oxygen were observed from the dam to the headwaters of both main embayments (Figures 6 and 7). Anoxic conditions developed more rapidly and were more extensive in the

Seneca River arm than in the Tugaloo River arm, possibly the result of greater introduction of organic material is indicated by elevated nutrient concentrations in the upper reaches of the Seneca River embayment. Hypolimnetic oxygen depletion was initially observed in the mid-reaches of both embayments in June. Sustained releases through Hartwell Dam during the summer contributed to a reduction and downstream depletion of the anoxic zones in both upstream embayments. By mid-October, reaeration of the hypolimnion had occurred in both river arms due to normal seasonal cooling, although anoxic conditions persisted in the deeper stations of the Seneca River. Temporal and vertical changes in the concentration of dissolved oxygen were evident in the Hartwell Lake forebay area (Figure 8). Anoxia in this region was recorded in early September and, although significantly decreased, lingered in the bottom-most waters until early November.

In situ measurements of pH showed noticeable temporal variability but little longitudinal variability in Hartwell Lake (Figures 9 and 10). Minimum and maximum values in July were from 6.2 to 7.4, respectively, as compared to 5.9 to 6.5, respectively, in mid-October. Maximum values observed in July occurred in the forebay surface waters were the result of higher productivity in these areas.

Higher values of specific conductance, corresponding with anoxic conditions, were observed in the mid-reaches of both the Seneca and Tugaloo River embayments during July and in the deep water stations in October (Figures 11 and 12). While lakewide measurements of specific conductivity averaged 33 to 48 mS throughout much of the study period, conductance values in the anoxic waters of the Seneca River embayment, increased to a maximum of 77 mS in July, and to a maximum of 48 mS in the Tugaloo River embayment. Temporal and vertical changes in specific conductance data were observed at Station 210, where measurements ranged from 35 mS in March to 59 mS in October (Figure 13).

Summaries of Hartwell Lake epilimnetic and hypolimnetic in situ and water chemistry data were compiled and are shown for July and October of 1991 and 1992 (Tables 2 through 5). Mean values for each parameter in 1992 were overall lower than those observed for the previous year. As expected, seasonal trends in the concentrations of chemical variables, as well as longitudinal and vertical gradients, were most pronounced during the stratified period. Maximum concentrations in chemical constituents accompanied anoxic conditions in the bottom waters of the Seneca River embayment in July and in the deep, near-dam stations in October, but again, were lower than concentrations observed in 1991.

Concentrations of total phosphorus (TP) in the Seneca River embayment ranged from 0.010 to 0.019 mg/l in July and was primarily accumulated in the headwaters, while in October, concentrations ranged from 0.01 to 0.04 mg/l and were well distributed throughout the entire arm. In the Tugaloo River embayment, however, concentrations ranged from 0.005 to 0.011 mg/l in July, but showed greatest accumulation in the deeper, near-dam stations. October TP concentrations ranged from 0.016 to 0.028 mg/l and, as with the Seneca River arm, were well distributed throughout the embayment (Figures 14 and 15). Increased levels of concentration in TP in the headwaters during oxidized conditions is probably associated with loading from external sources. July measurements of total soluble phosphorus (TSP) and soluble reactive phosphorus (SRP) concentrations in both embayments were recorded at or just above the detection limits of the analytical instruments. October measurements for TSP ranged from 0.008 to 0.012 mg/l in the Seneca River arm and from 0.011 to 0.007 mg/l in the Tugaloo River arm. October SRP measurements for both embayments were at or just below detection limits (Figures 16-19).

Total nitrogen (TN) concentrations reflected both temporal and spatial gradients which corresponded to anoxic conditions in Hartwell Lake. Seneca River concentrations ranged from 0.2 to 0.5 mg/l with highest concentrations in the anoxic areas of the headwaters and in the deeper forebay waters. October concentrations also ranged from 0.2 to 0.5 mg/l, but showed greatest accumulation in the forebay waters (Figure 20). Concentrations of TN in the Tugaloo River arm in July ranged from 0.2 to 0.4 mg/l but were well distributed. October levels were in the same concentration range, but again, were accumulated in the deep waters of the forebay region (Figure 21). Dissolved nitrogen (DN) concentrations were slightly lower than total nitrogen but followed approximately the same distribution patterns in both major embayments (Figures 22 and 23). Maximum concentrations of ammonia-nitrogen were observed in response to anoxic conditions in the mid-reaches of both embayments in July and in the deep, near-dam stations in October. Increased levels in July is thought to be the result of the release of ammonia from the sediments under anaerobic conditions (Cole, 1988). Concentrations lakewide ranged from 0.0 to 0.2 mg/l (Figures 24 and 25).

Nitrate-nitrogen is routinely found in areas where oxygen is abundant. However, here it demonstrated an opposite trend, with elevated concentrations in the deep, anoxic, down-lake areas of both embayments in July and in the upper regions of the Seneca River embayment in October (Figure 26). July concentrations of nitrate-nitrogen ranged from 0.1 to 0.2 mg/l. Slightly increased levels of concentration in the upper Seneca River in October were related to the accumulation of ammonia oxidized during the process of destratification. By October, nitrate-nitrogen concentrations were below detection limits in the Tugaloo River arm of the lake (Figure 27). All of the nitrogen species were considerably lower in 1992 than in 1991.

Temporal and spatial gradients in organic carbon concentrations corresponded with anoxic conditions in Hartwell Lake. Concentrations of total organic carbon (TOC) in July ranged from 0.4 to 1.8 mg/l in the Seneca River embayment and from 0.4 to 1.2 mg/l in the Tugaloo River embayment (Figures 28 and 29). Dissolved organic carbon (DOC) concentrations in July followed similar patterns, ranging from 0.4 to 1.6 mg/l and from 0.4 to 1.2 mg/l in the Seneca and Tugaloo River arms, respectively. During October, concentrations in both embayments ranged from 1.2 to

1.6 mg/l, with the highest concentrations distributed throughout the deeper areas near the dam (Figures 30 and 31).

Distribution patterns in total alkalinity concentrations were observed in July and October and are depicted in Figures 32 and 33. Variability in these concentrations coincided with the presence of anoxic conditions, ranging from 7.0 to 18.0 mg/l in the middle reaches of each embayment in July, and from 8.0 to 22.0 mg/l in the near dam stations in October.

Gradients in turbidity relative to tributary inflows were recorded in both the Seneca and Tugaloo Rivers (Figures 34 and 35). The Seneca River arm showed greatest variability in July with concentrations ranging from 5 to 30 NTU in the upper reaches, compared to 2 to 10 NTU found in the upper reaches of the Tugaloo River. Increased values in turbidity under anoxic conditions may be more indicative of interactions at the sediment/water interface than of increased biological activity. In October, both embayments showed upstream gradients of 0 to 15 NTU with maximum values being recorded in the upper reaches of the Seneca River as well as in the deep, near dam stations. Distribution patterns and concentrations for nutrients followed much the same trends as those observed in 1991. A close review of the data for all chemical constituents showed no significant changes in trends or concentrations in Hartwell Lake for 1992.

Temperature, dissolved oxygen, pH, and specific conductance were monitored in the Hartwell Dam tailrace using a Schneider RM-25 Monitoring System, however, actual data collection did not begin until mid-March due to mechanical difficulties. These variables exhibited seasonal trends which reflected changing conditions in the forebay of Hartwell Lake. Temperatures ranged from 10.7 °C in late March to 14.5 °C in July, before reaching a maximum of 20 °C in mid-October. Dissolved oxygen concentrations were nearly 11 mg/l in late March and ranged from 2 to 4 during the late-summer stratified period when anoxic conditions were prevalent in the deep water areas of Hartwell Lake. By early November, average concentrations had risen to 8 mg/l, which corresponded to fall mixing in the lake (Figure 36). Seasonal variability in pH values were also observed in the Hartwell Dam tailrace, averaging 6.7 in March, 6.1 in July, and 6.3 during October (Figure 37). Specific conductance values were reflective of the low conductivity measurements observed in the Hartwell forebay throughout the year, ranging from 30 to 38 mS (Figure 38). Major shifts observed in Figure 38 were related to mechanical and calibration difficulties in the RM-25 Monitor later in the year.

Summary

This report documents the results of comprehensive water quality studies performed in Hartwell Lake (HW) during the period January through December 1992. Presented in this report are summaries and comparisons of water quality conditions observed during monthly in situ sampling trips and biannual chemical sampling trips within the main stem and two major embayments on Hartwell Lake.

The onset of thermal stratification began in Hartwell Lake during early March and by mid-April, extensive stratification was present from the headwaters of each major embayment to the forebay. Anoxic conditions were observed in the middle reaches of the Seneca and Tugaloo Rivers during the July sampling trip. The greatest concentrations of chemical constituents within the two embayments were also recorded during the mid-July sampling period. By mid-October, stratification in the upstream regions had diminished due to normal seasonal cooling, but persisted in the deeper waters of the forebay until early November.

Intensive physicochemical sampling during July, revealed increased concentrations of specific nutrients and organic carbons normally associated with anoxic conditions in the bottom waters of an embayment. Concentrations of those nutrients within the middle reaches of the Seneca River embayment were consistently greater than those concentrations observed in the Tugaloo River embayment. A subsequent sampling trip in October indicated that anoxic conditions within the two primary embayments no longer existed. Anoxia did, however, persist in the deeper, near-dam stations and was confirmed by the presence of greater concentrations of chemical variables.

Continuous data for temperature, dissolved oxygen, pH, and specific conductivity were collected using a Schneider RM-25 monitor in the tailrace below Hartwell Dam. These data reflected seasonal variability and were indicative of water quality conditions in the forebay of Hartwell Lake.

Hartwell Dam outflows were fairly consistent in response to precipitation and inflow levels early in the year, but nearly doubled September through November and were more than four times greater in December, this due to a tremendous increase in precipitation during November. Inflows were also much higher in those months due to greater than average rainfall during August through December, nearly double the inflows observed in 1991.

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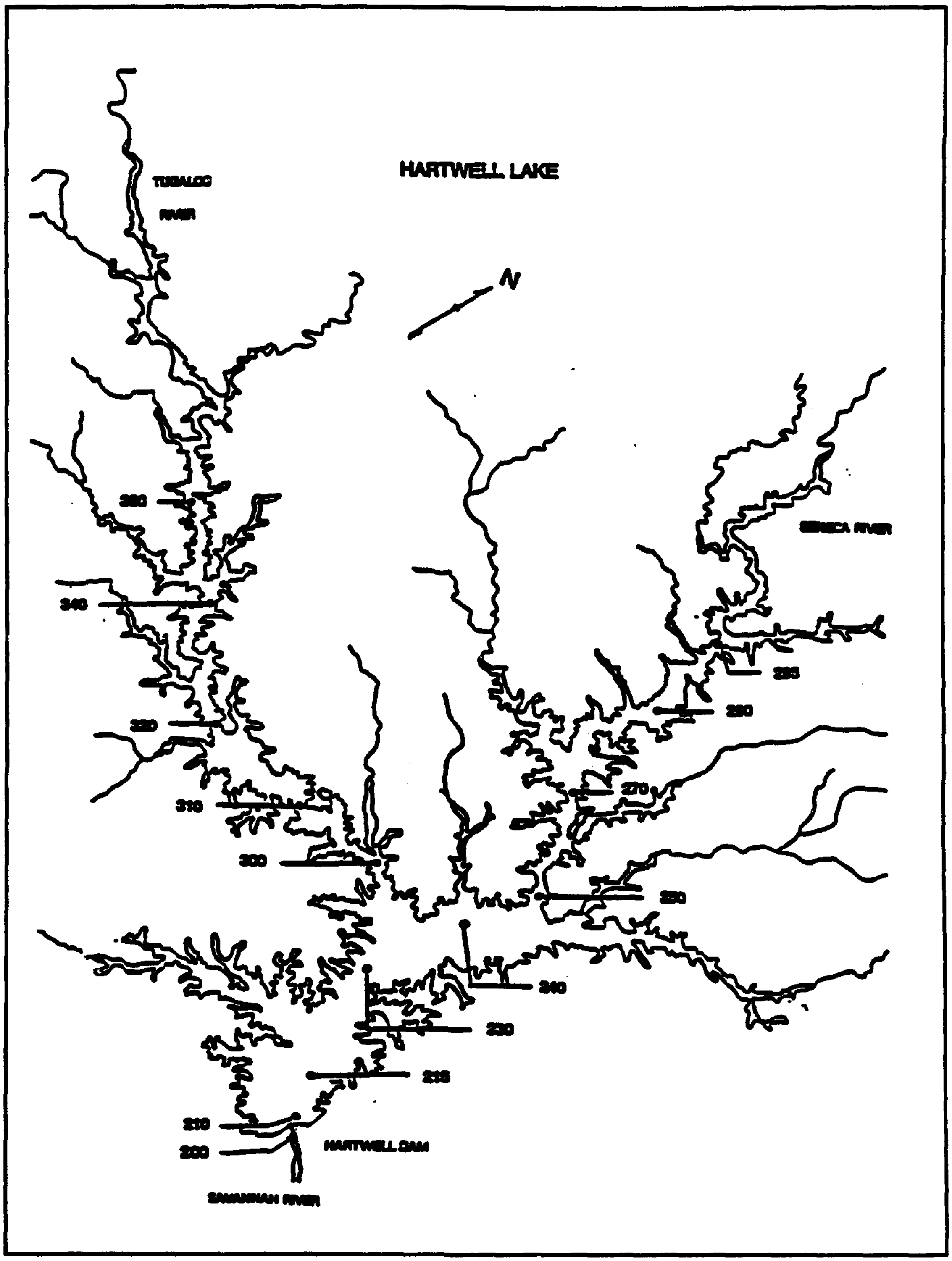


Figure 1. Sampling stations in Hartwell Lake and tailrace

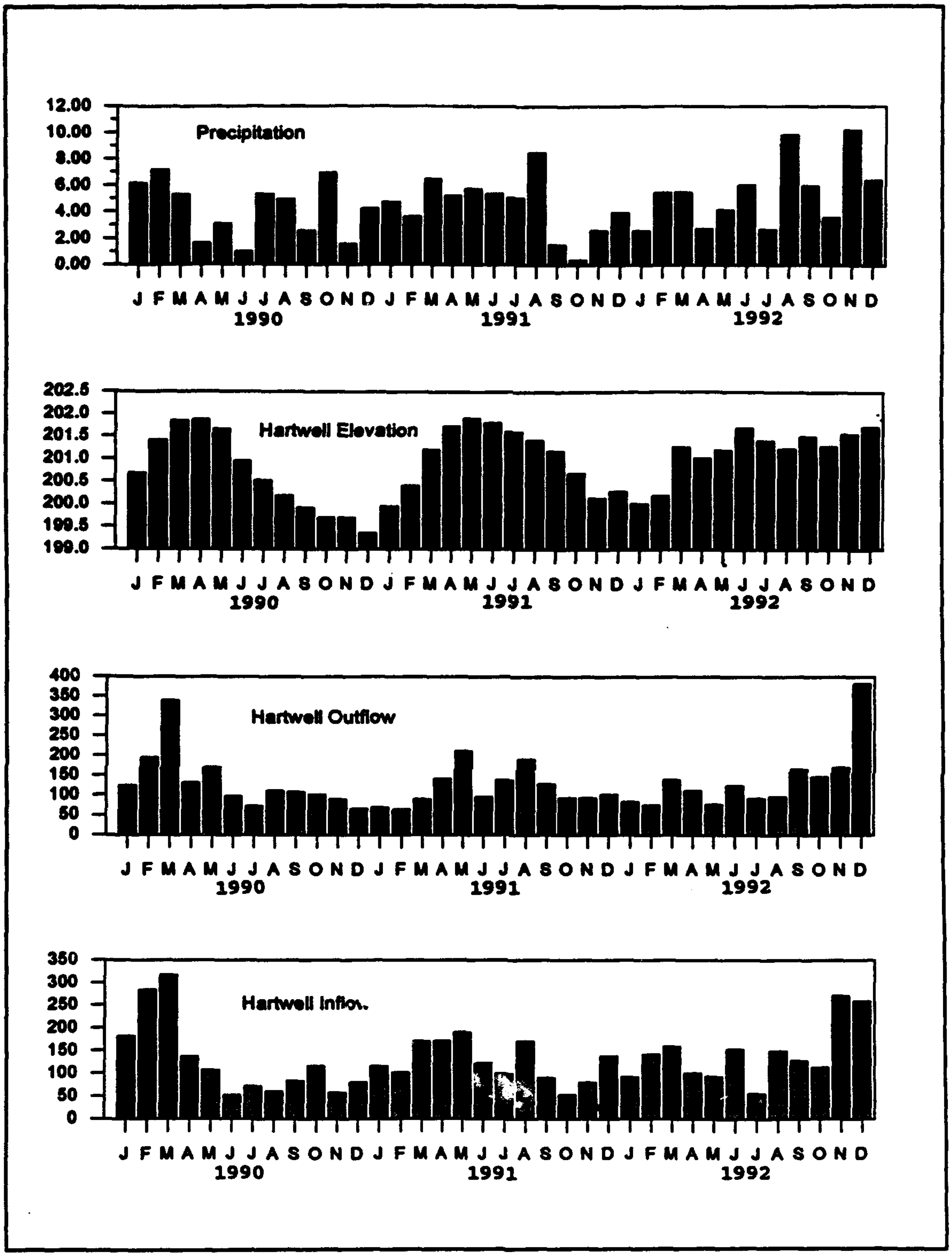


Figure 2. Precipitation, pool elevation, mean daily inflow and mean daily outflow for Hartwell Lake, 1990-1992

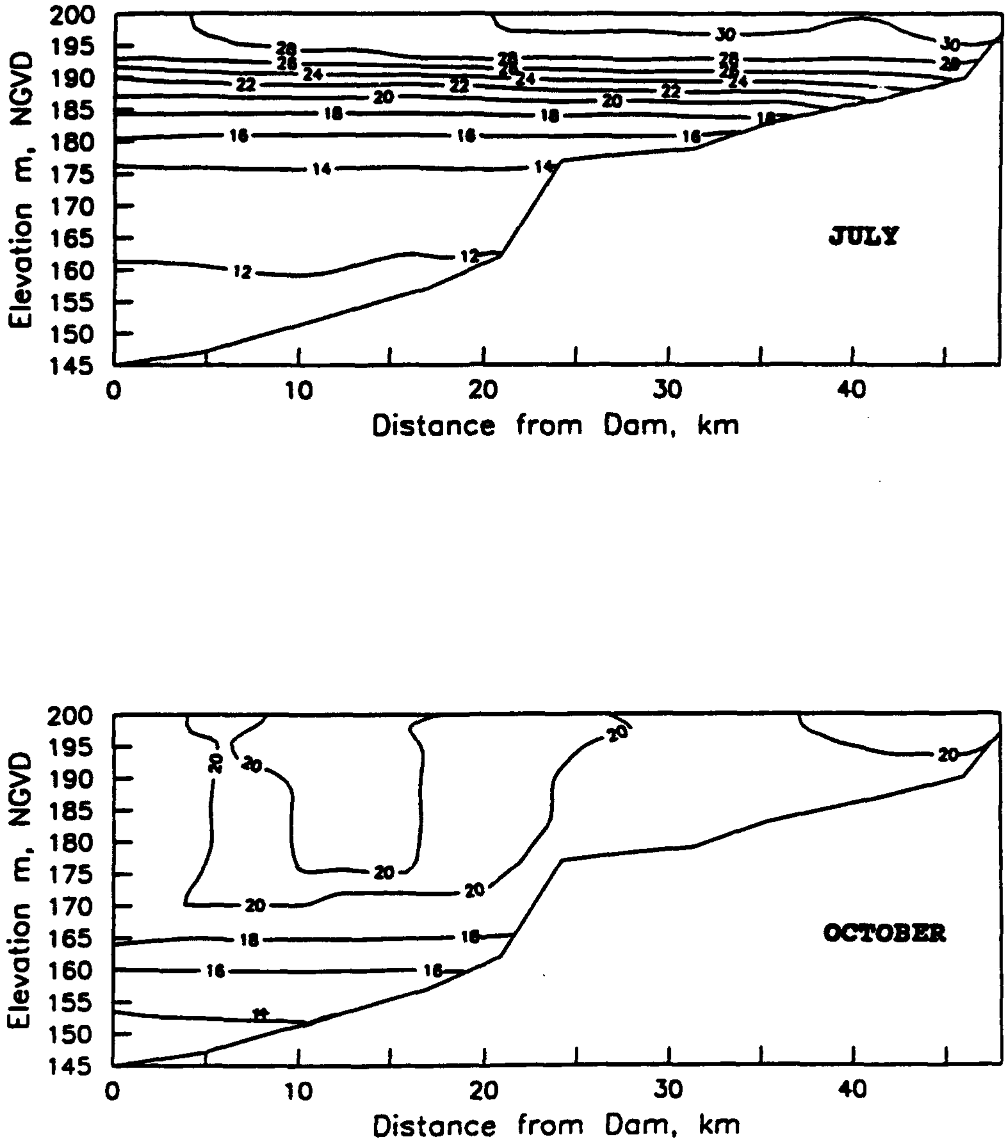


Figure 3. Patterns of spatial distribution of temperatures (°C) from Hartwell Dam to upper Seneca River, July and October, 1992

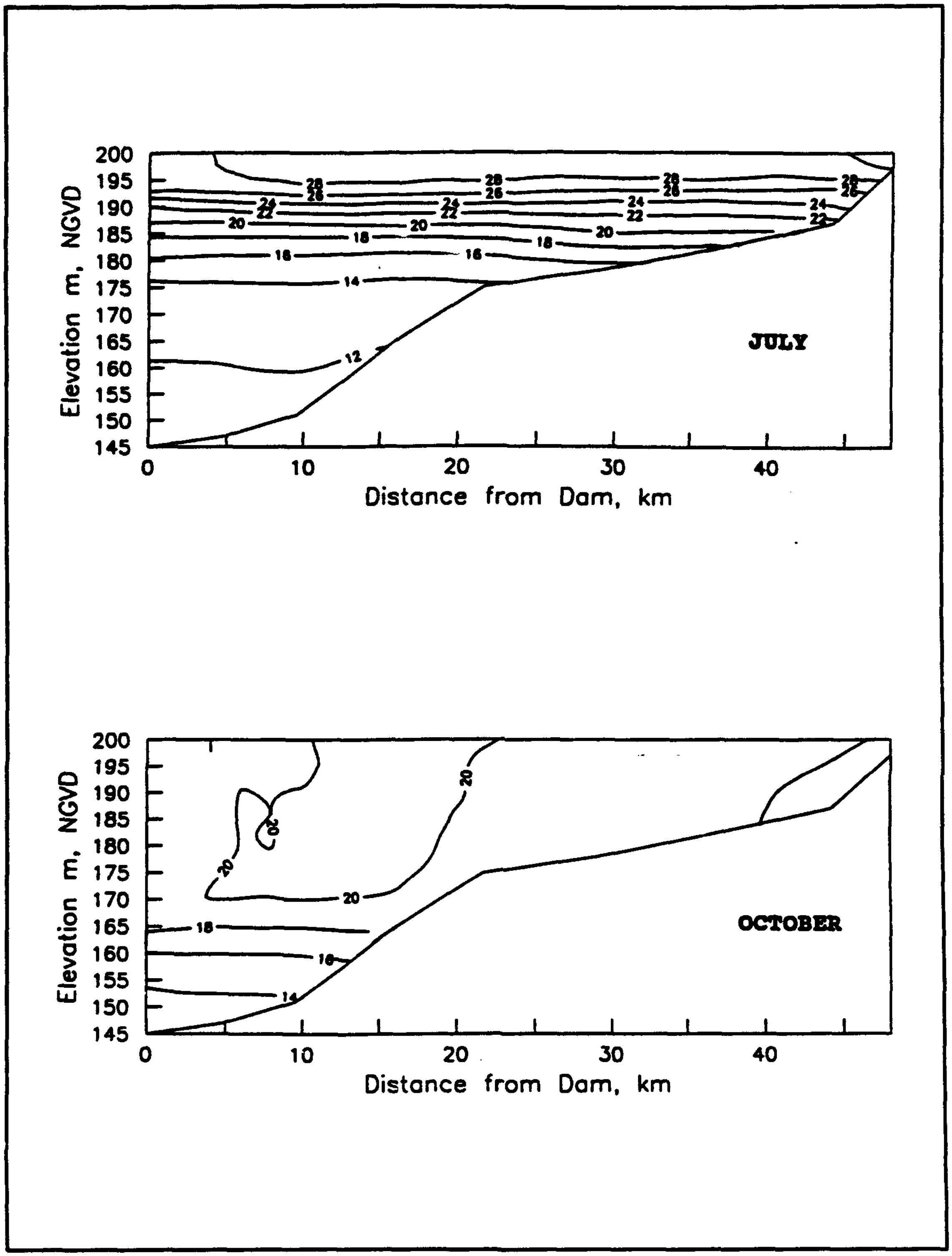


Figure 4. Patterns of spatial distribution of temperatures (°C) from Hartwell Dam to upper Tugaloo River, July and October, 1992

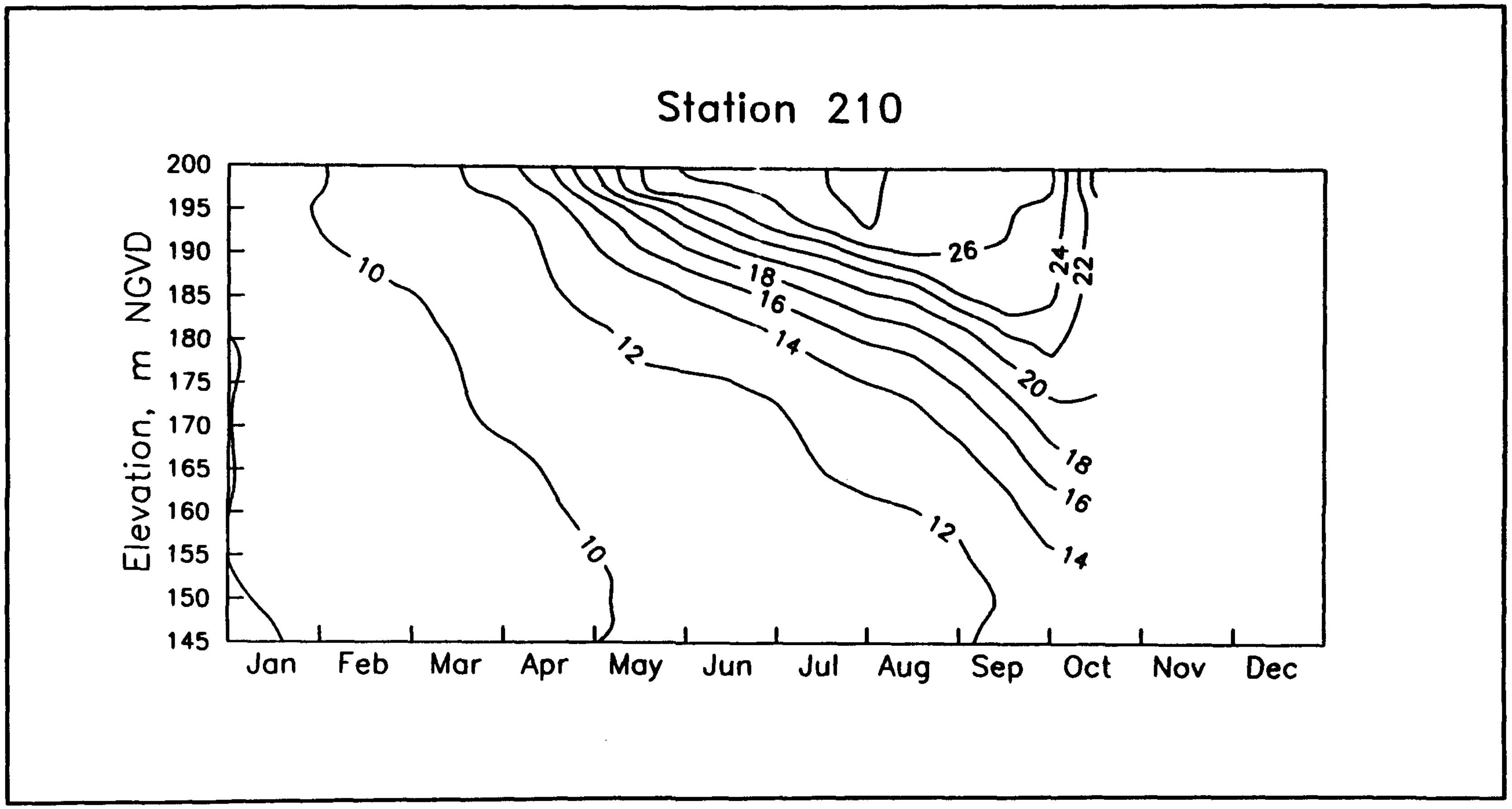


Figure 5. Temporal and vertical changes in temperature (°C) in the forebay of Hartwell Lake (Station 210)

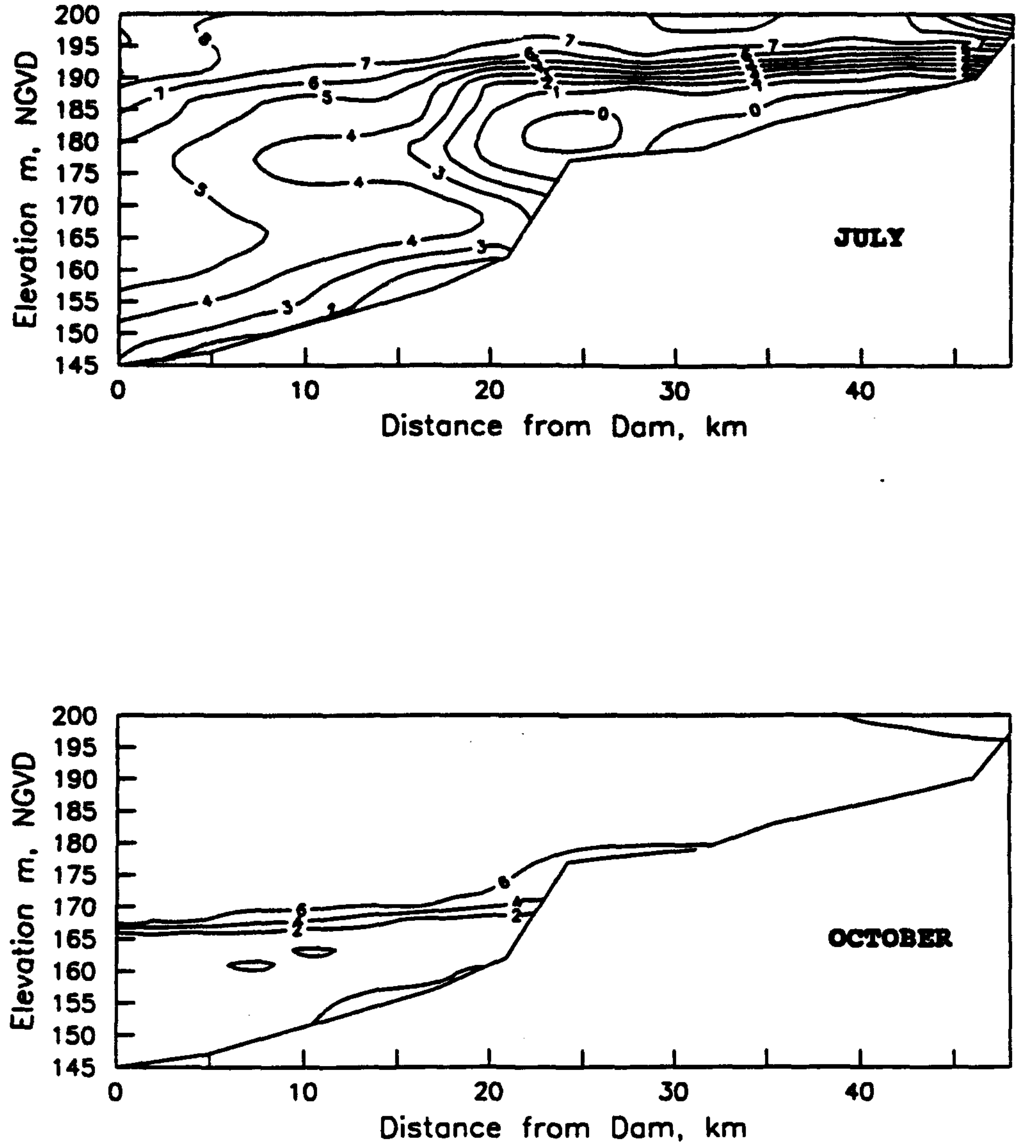


Figure 6. **Patterns of spatial distribution of dissolved oxygen concentrations (mg/l) from Hartwell Dam to upper Seneca River, July and October, 1992**

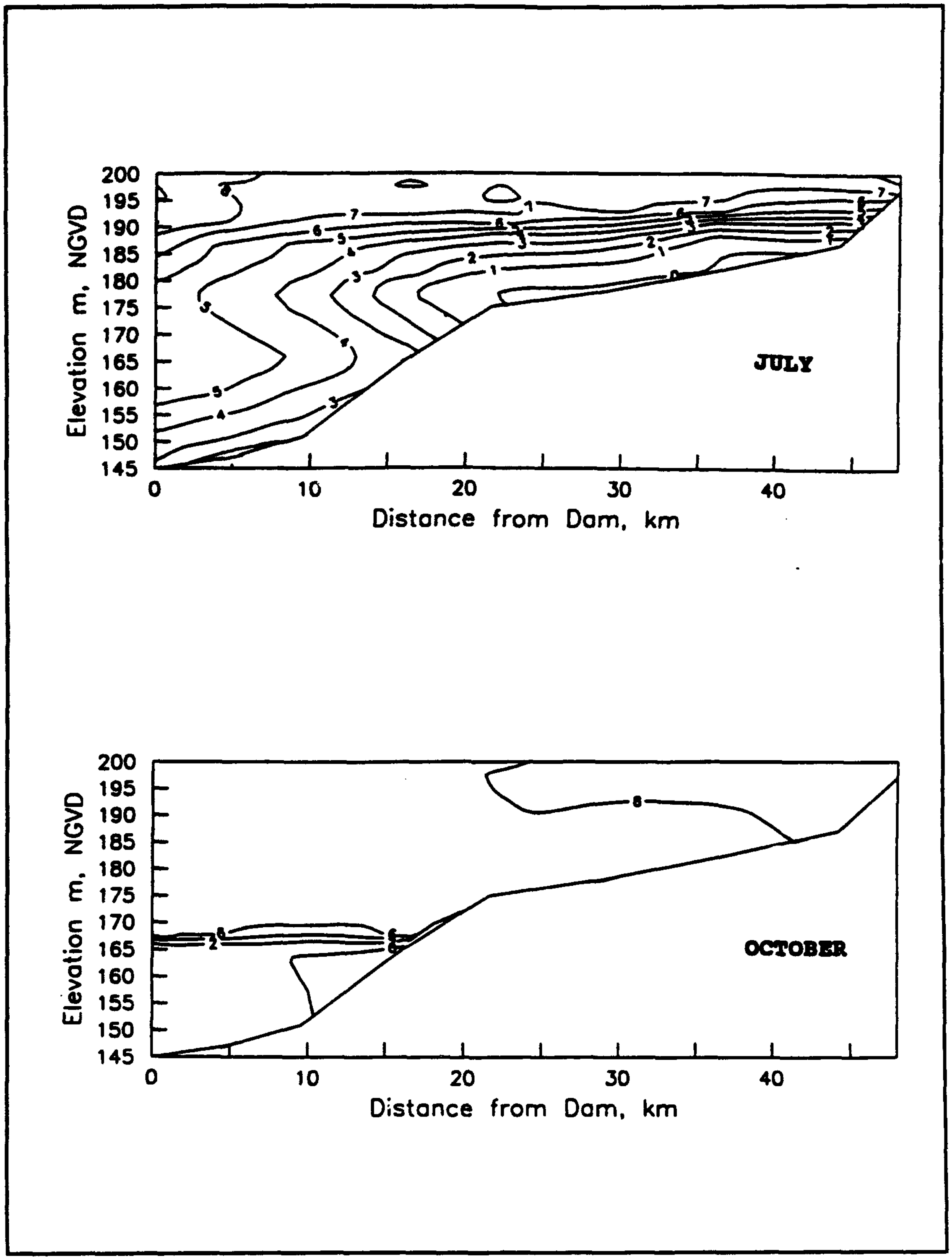


Figure 7. Patterns of spatial distribution of dissolved oxygen concentrations (mg/l) from Hartwell Dam to upper Tugaloo River, July and October, 1992

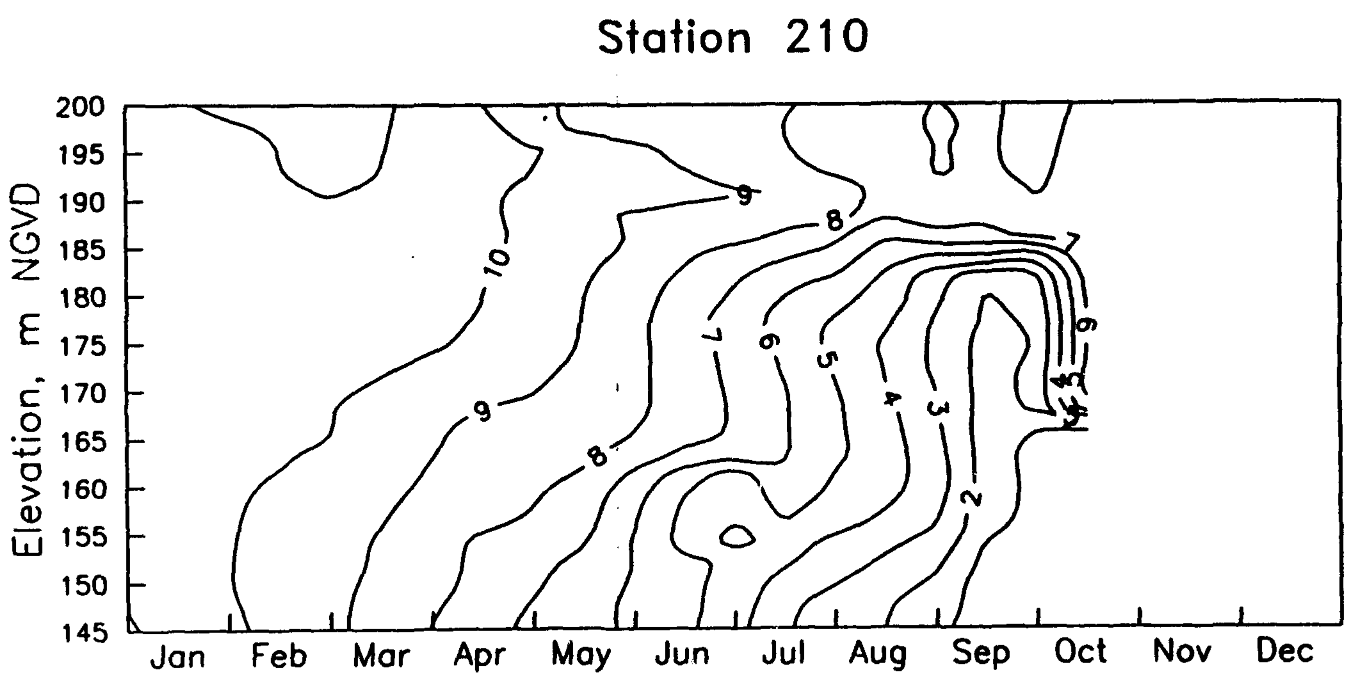


Figure 8. Temporal and vertical changes in dissolved oxygen (°C) in the forebay of Hartwell Lake (Station 210)

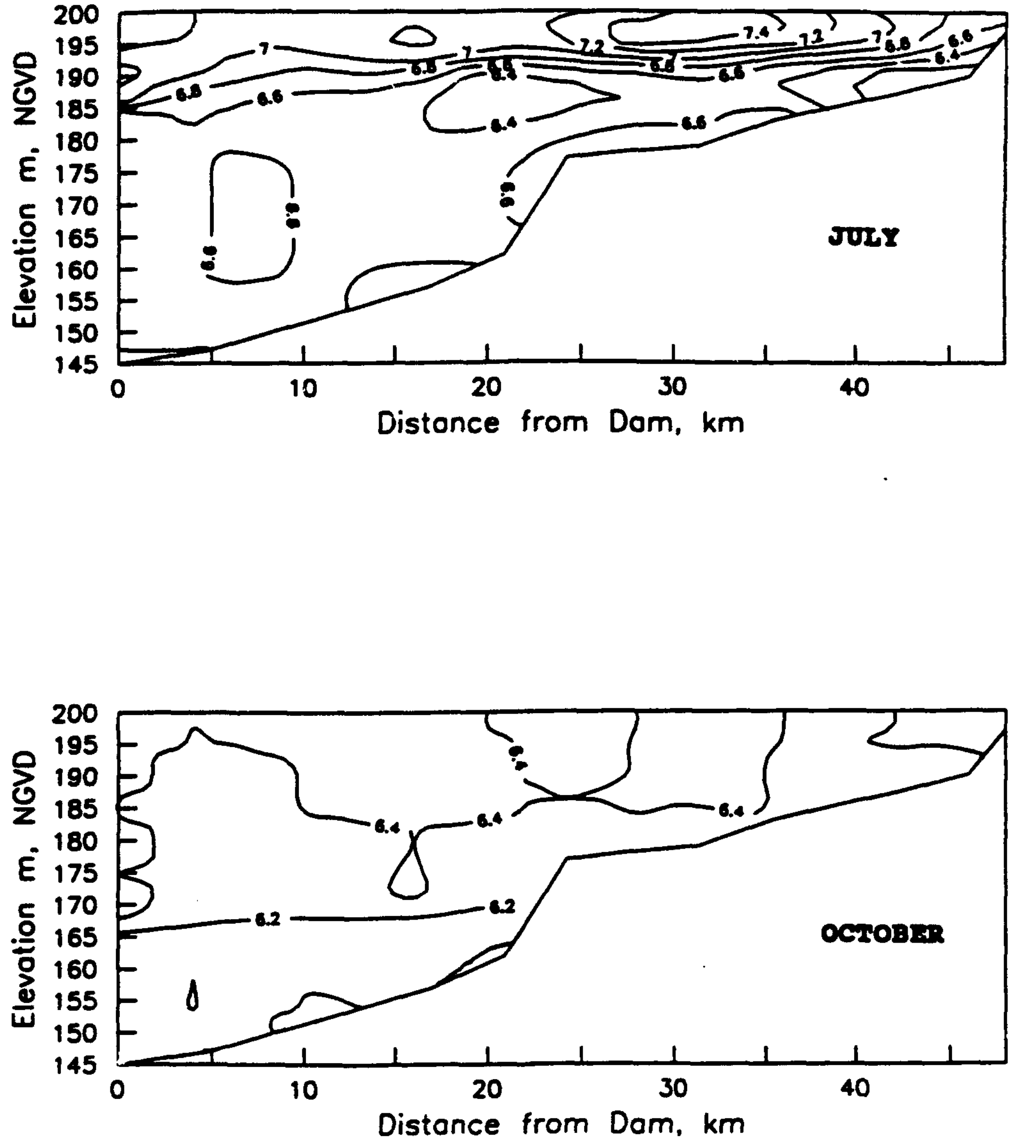


Figure 9. Patterns of spatial distribution of ph (ph units) from Hartwell Dam to upper Seneca River, July and October, 1992

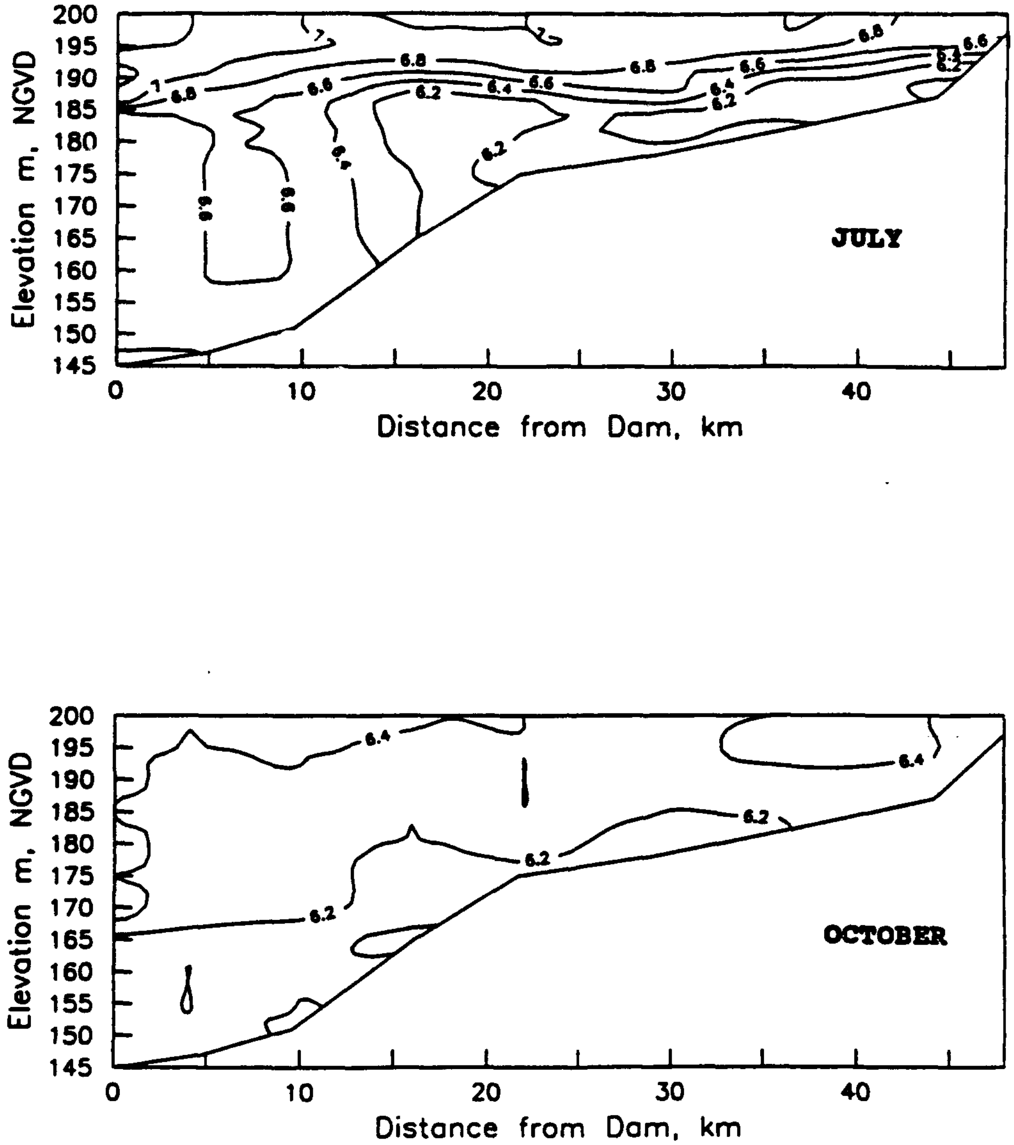


Figure 10. Patterns of spatial distribution of ph (ph units) from Hartwell Dam to upper Tugaloo River, July and October, 1992

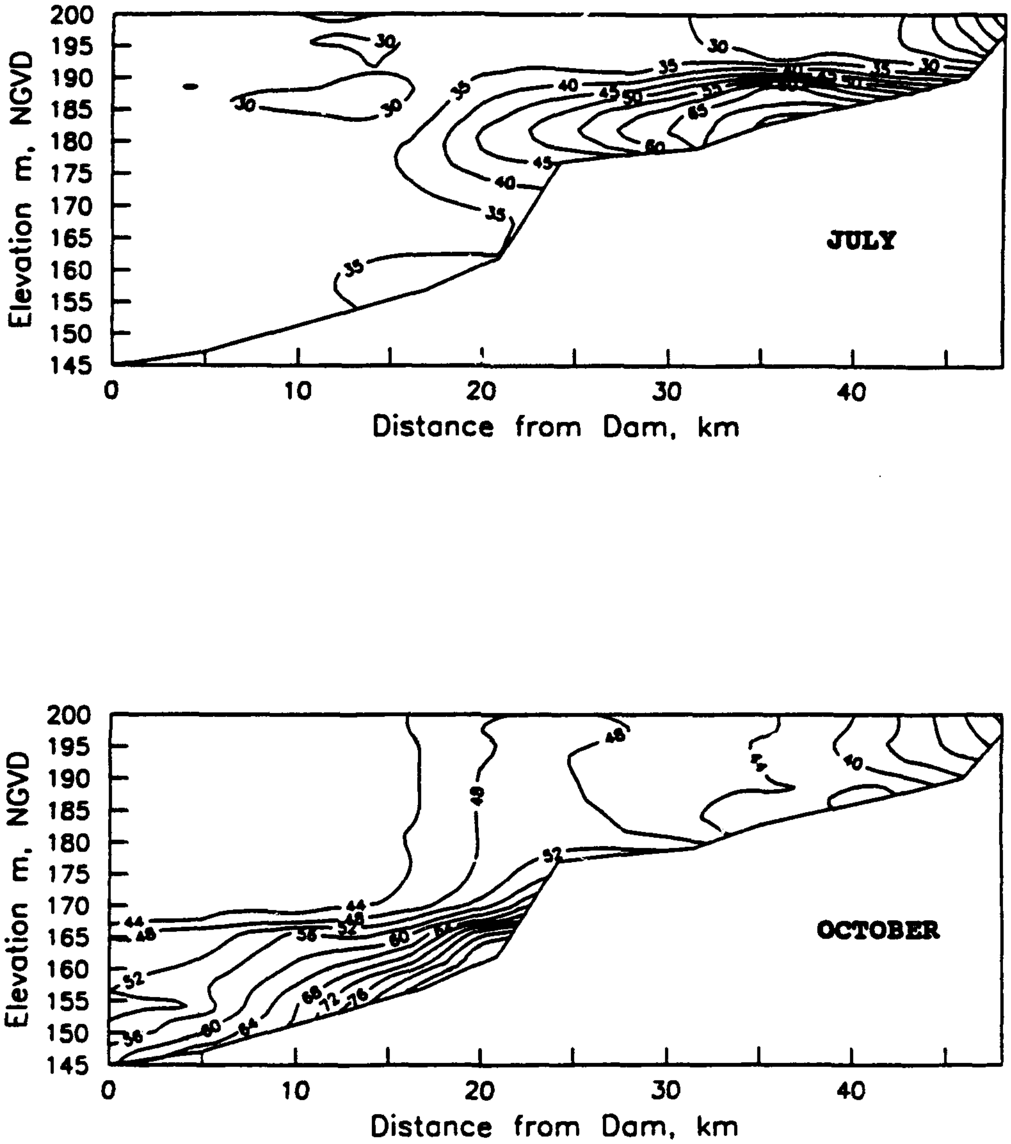


Figure 11. Patterns of spatial distribution of specific conductance (µS) from Hartwell Dam to upper Seneca River, July and October, 1992

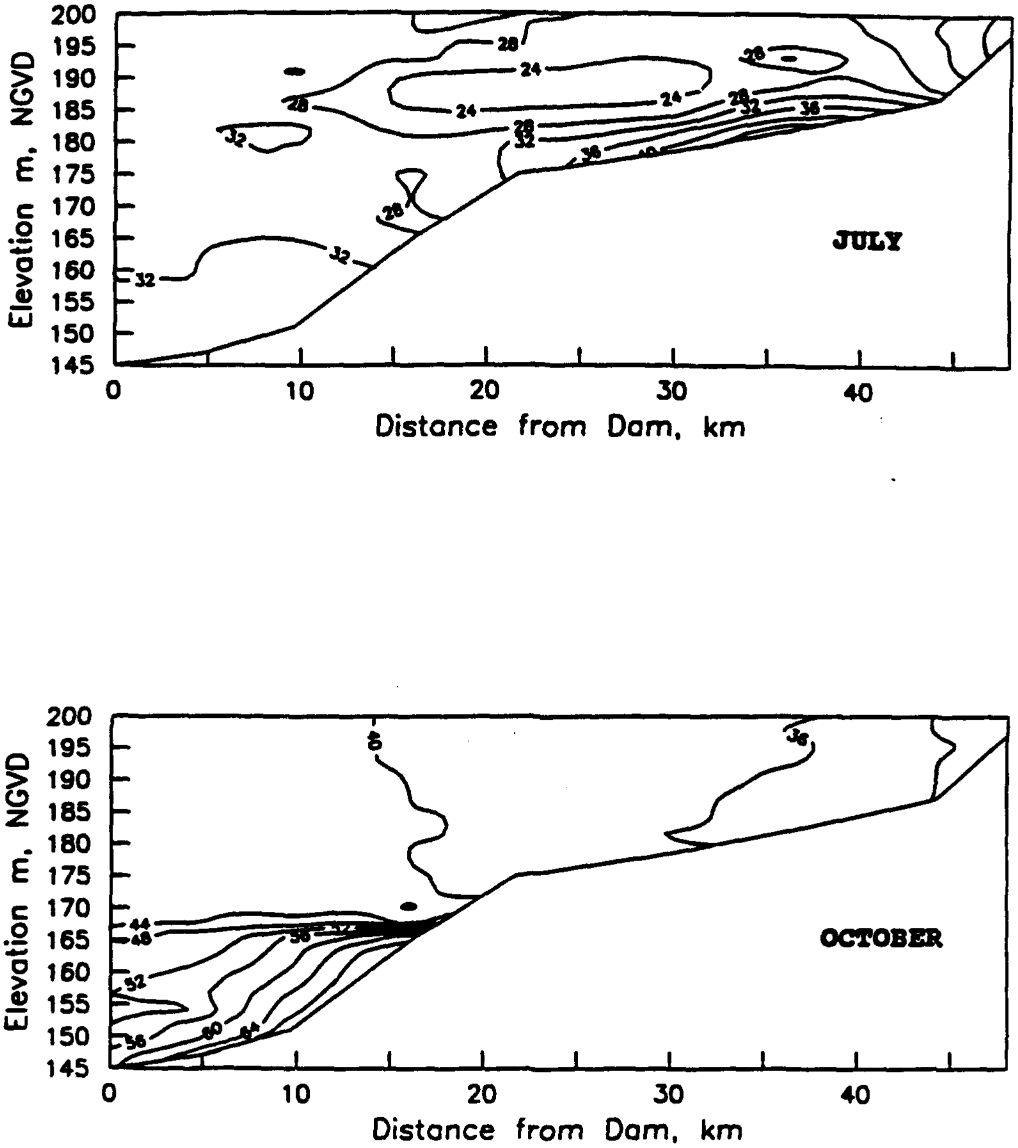


Figure 12. Patterns of spatial distribution of specific conductance (µS) from Hartwell Dam to upper Tugaloo River, July and October, 1992

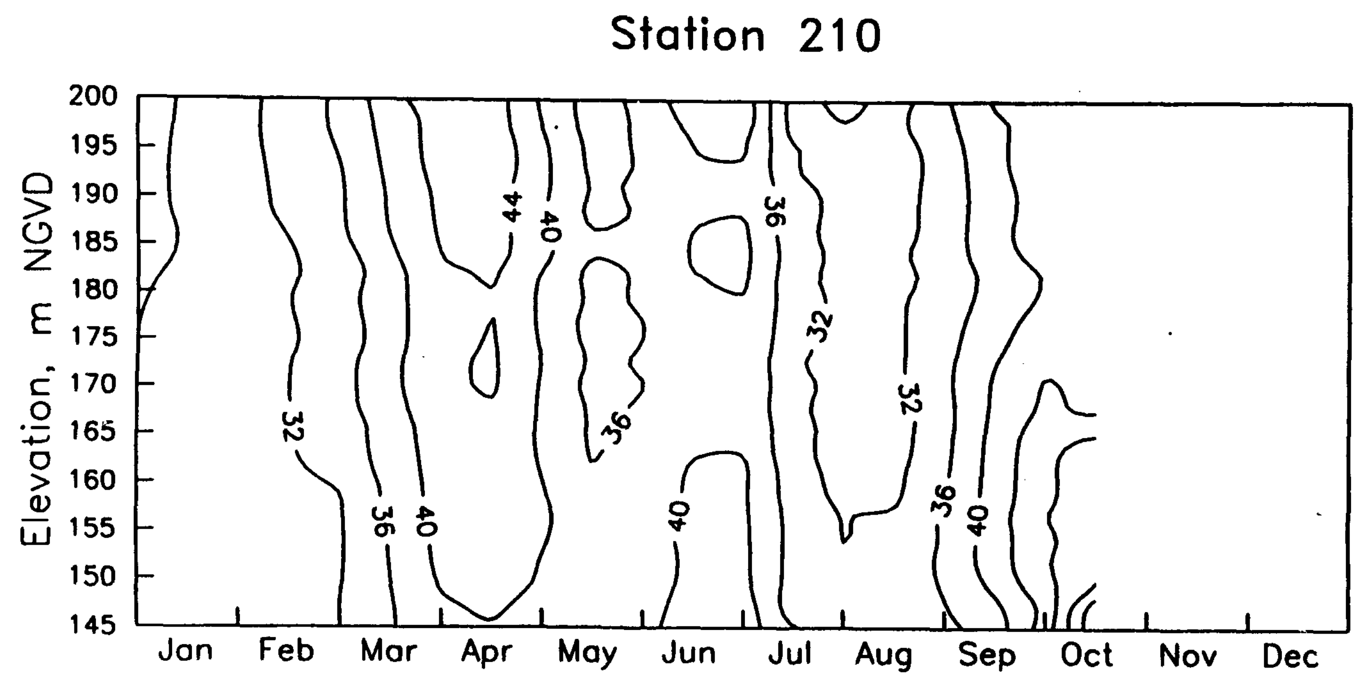


Figure 13. Temporal and vertical changes in specific conductance (µS) in the forebay of Hartwell Lake (Station 210)

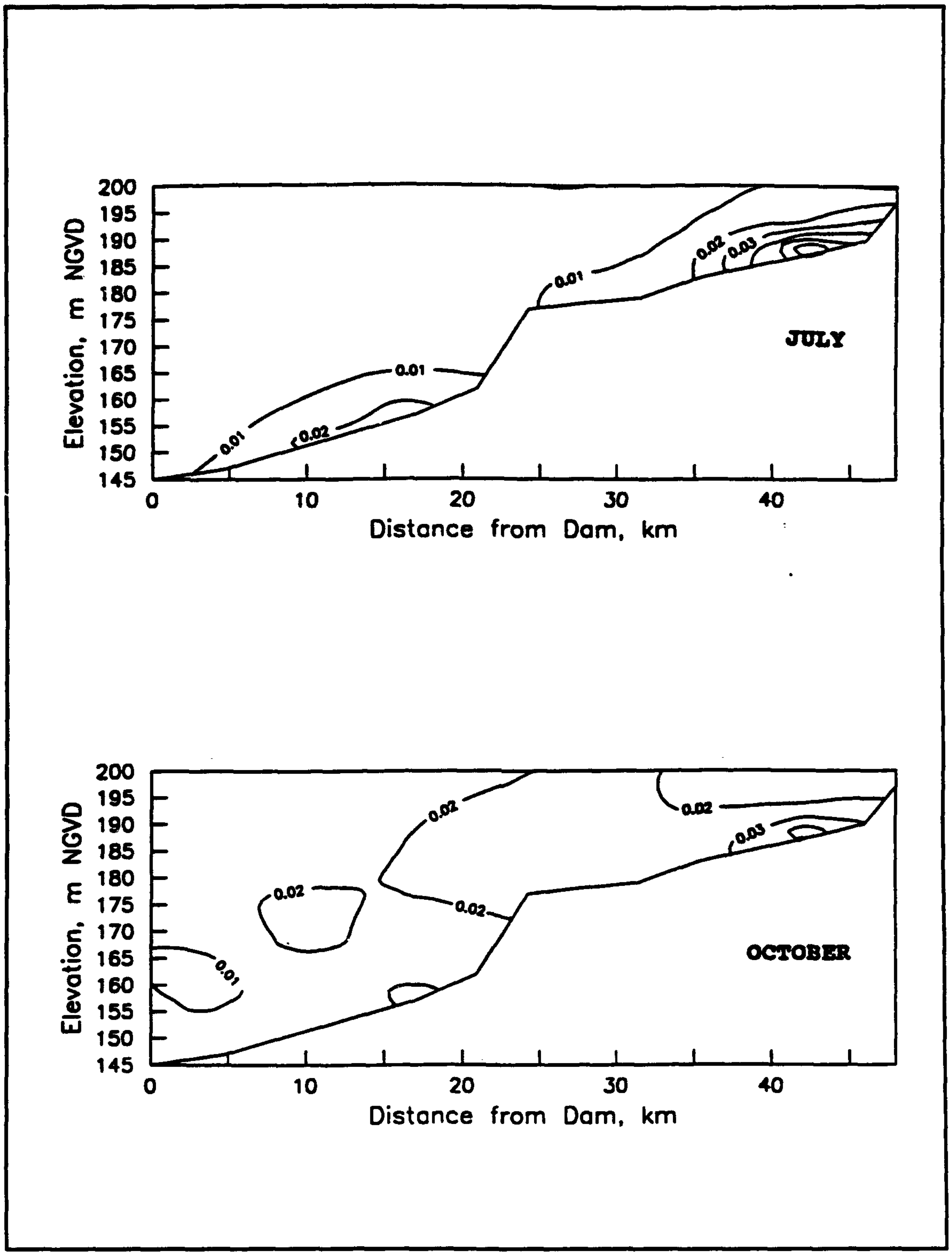


Figure 14. Patterns of spatial distribution of total phosphorus concentrations (mg/l) from Hartwell Dam to upper Seneca River, July and October, 1992

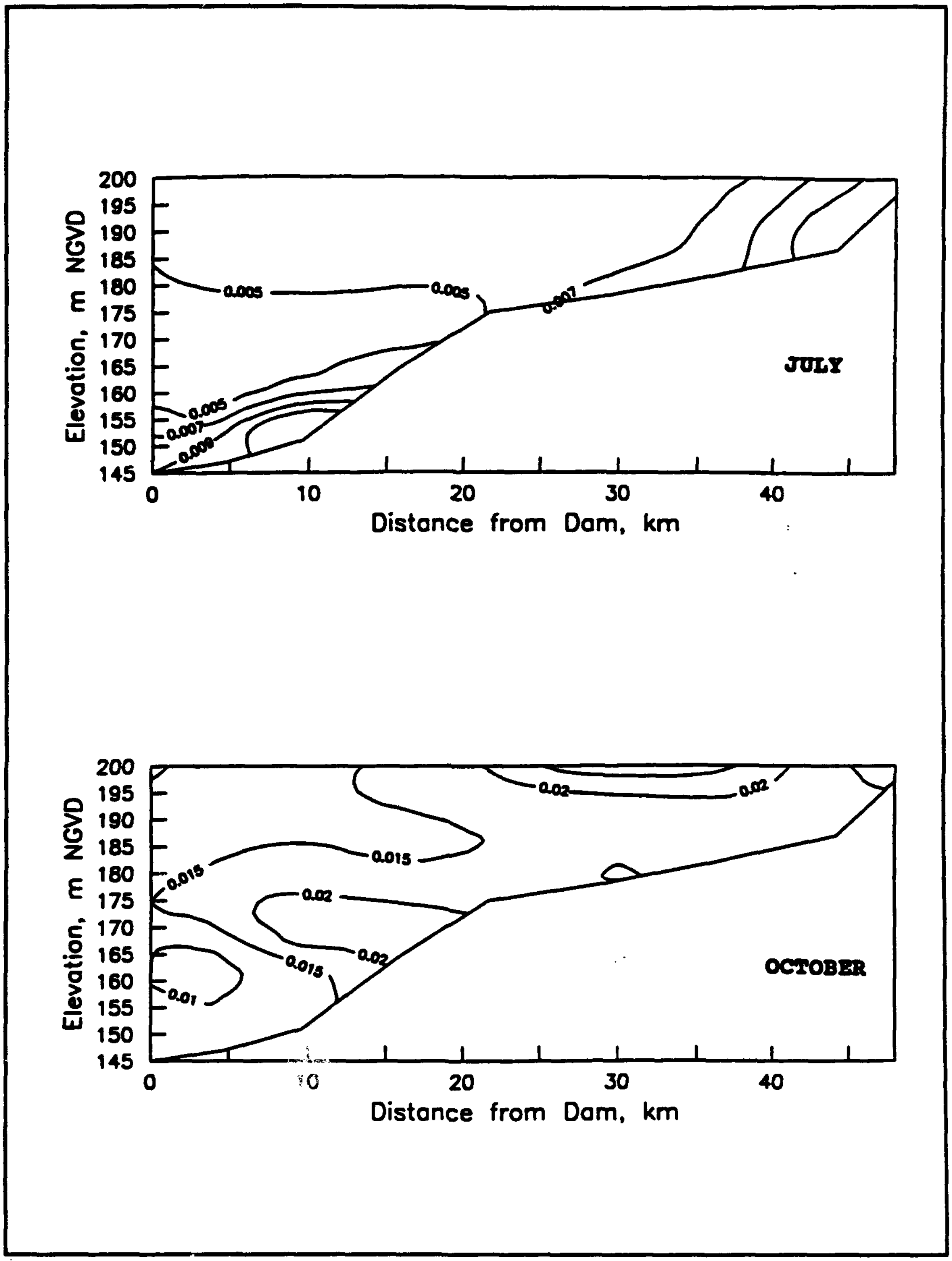


Figure 15. Patterns of spatial distribution of total phosphorus concentrations (mg/l) from Hartwell Dam to upper Tugaloo River, July and October, 1992

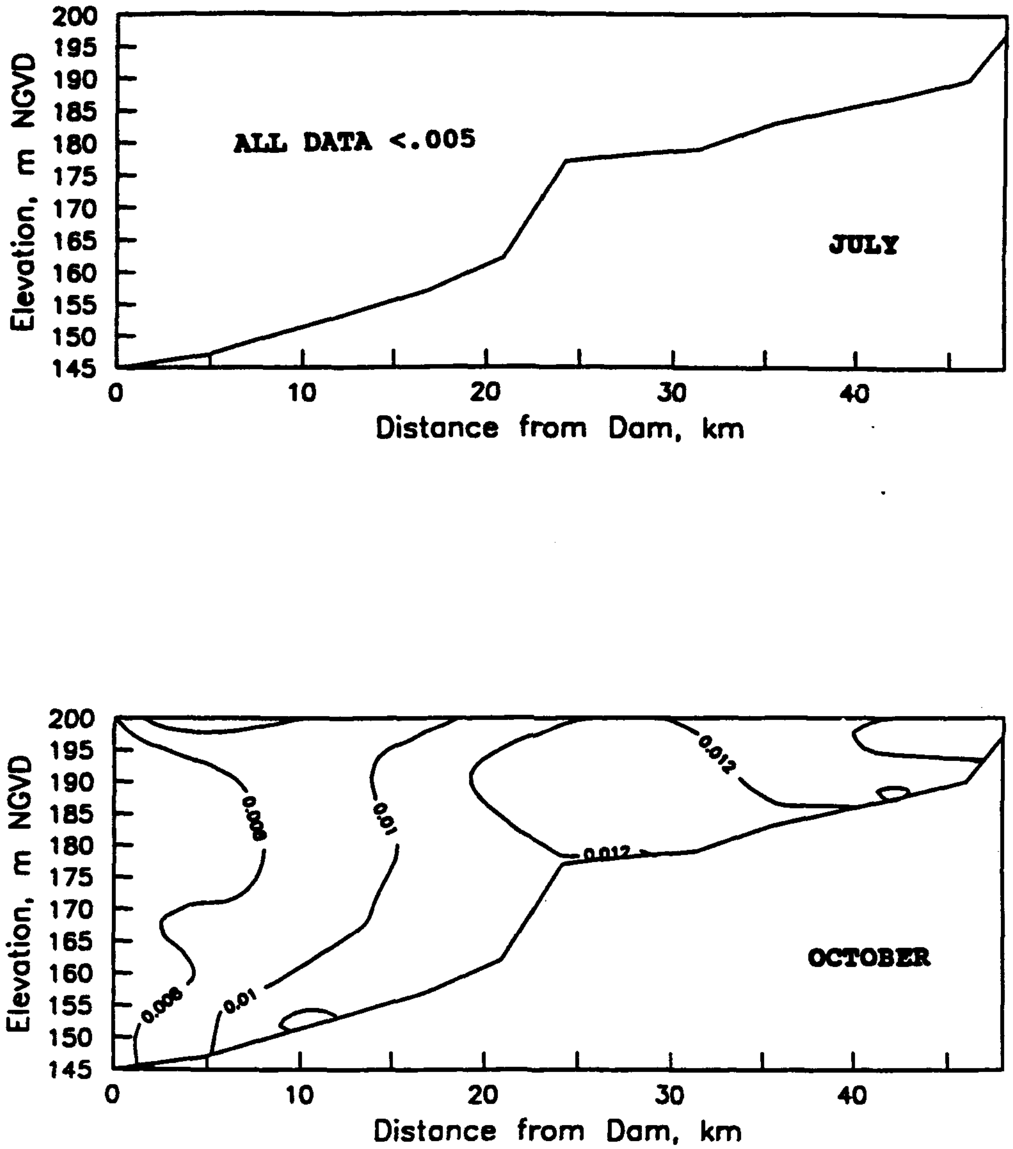


Figure 16. Patterns of spatial distribution of total soluble phosphorus concentrations (mg/l) from Hartwell Dam to upper Seneca River, July and October, 1992

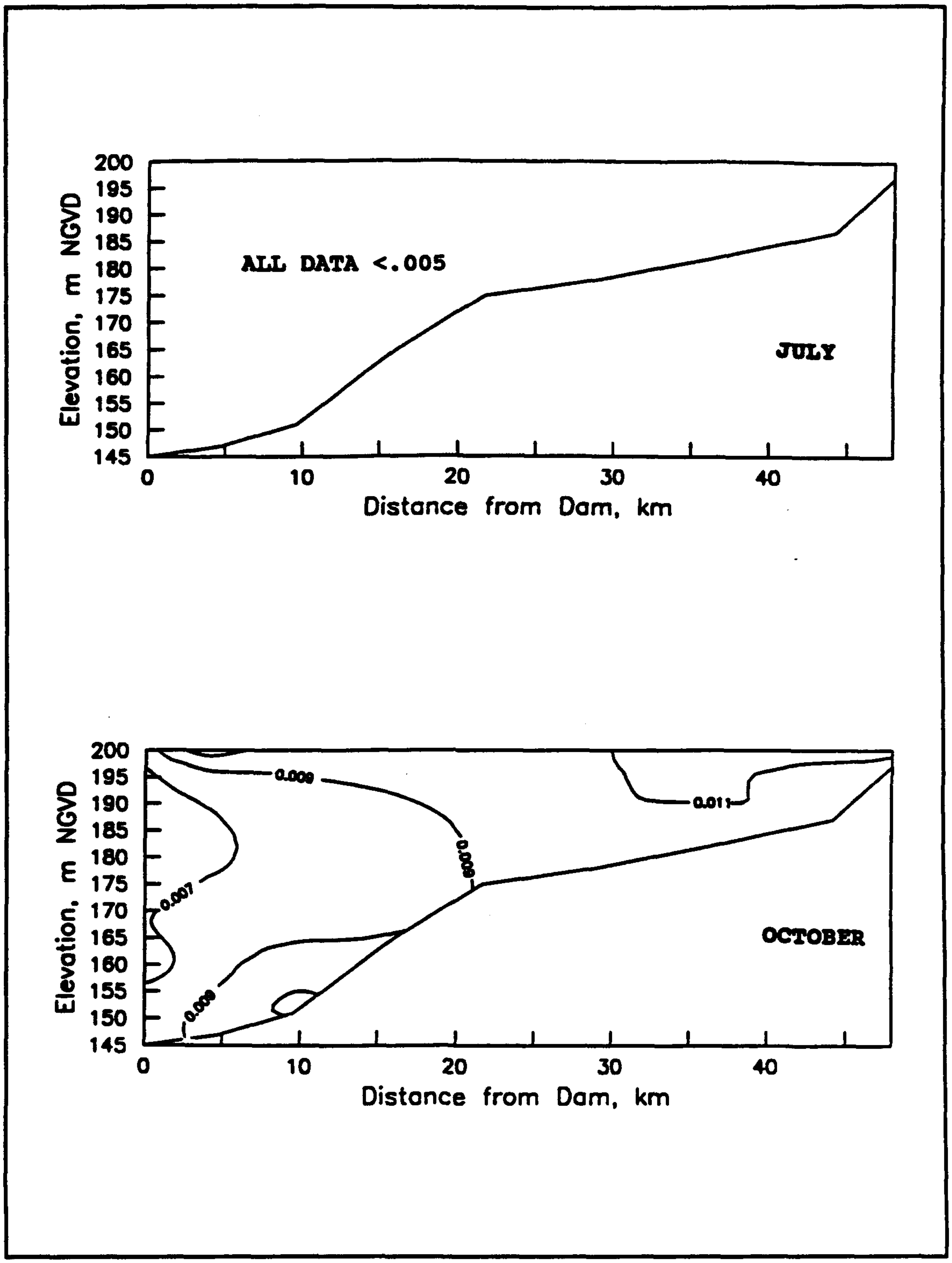


Figure 17. Patterns of spatial distribution of total soluble phosphorus concentrations (mg/l) from Hartwell Dam to upper Tugaloo River, July and October, 1992

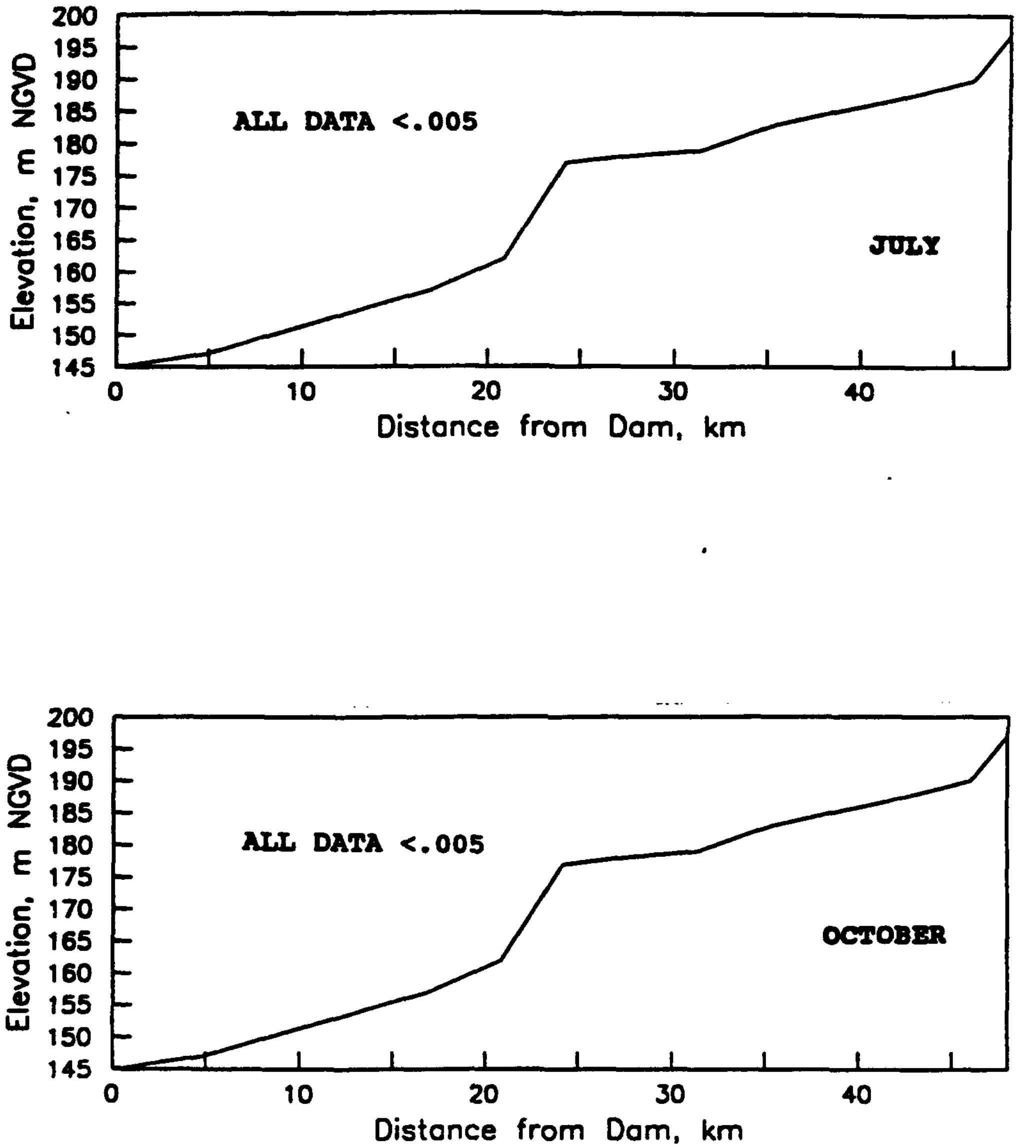


Figure 18. Patterns of spatial distribution of soluble reactive phosphorus concentrations (mg/l) from Hartwell Dam to upper Seneca River, July and October, 1992

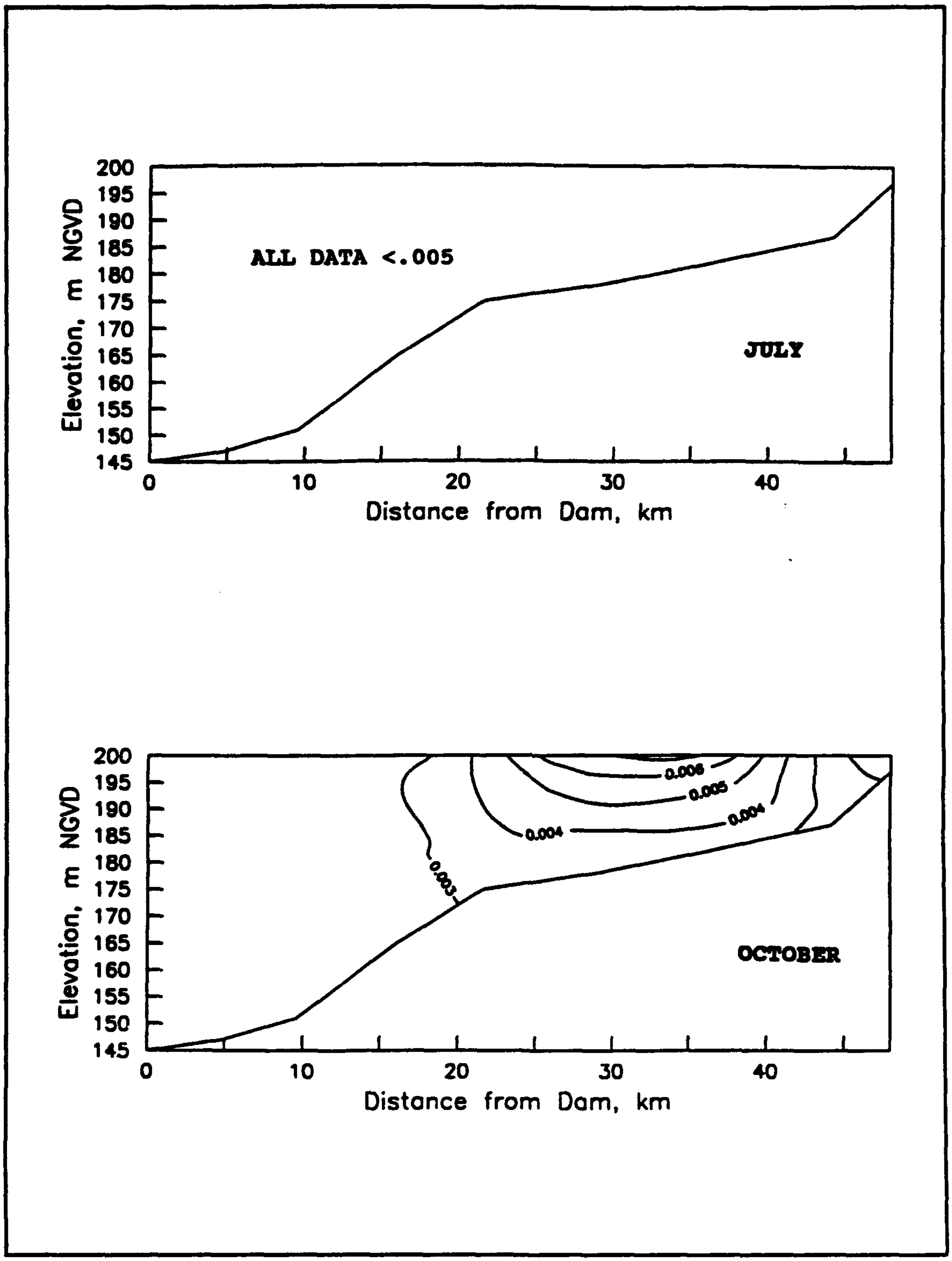


Figure 19. Patterns of spatial distribution of soluble reactive phosphorus concentrations (mg/l) from Hartwell Dam to upper Tugaloo River, July and October, 1992

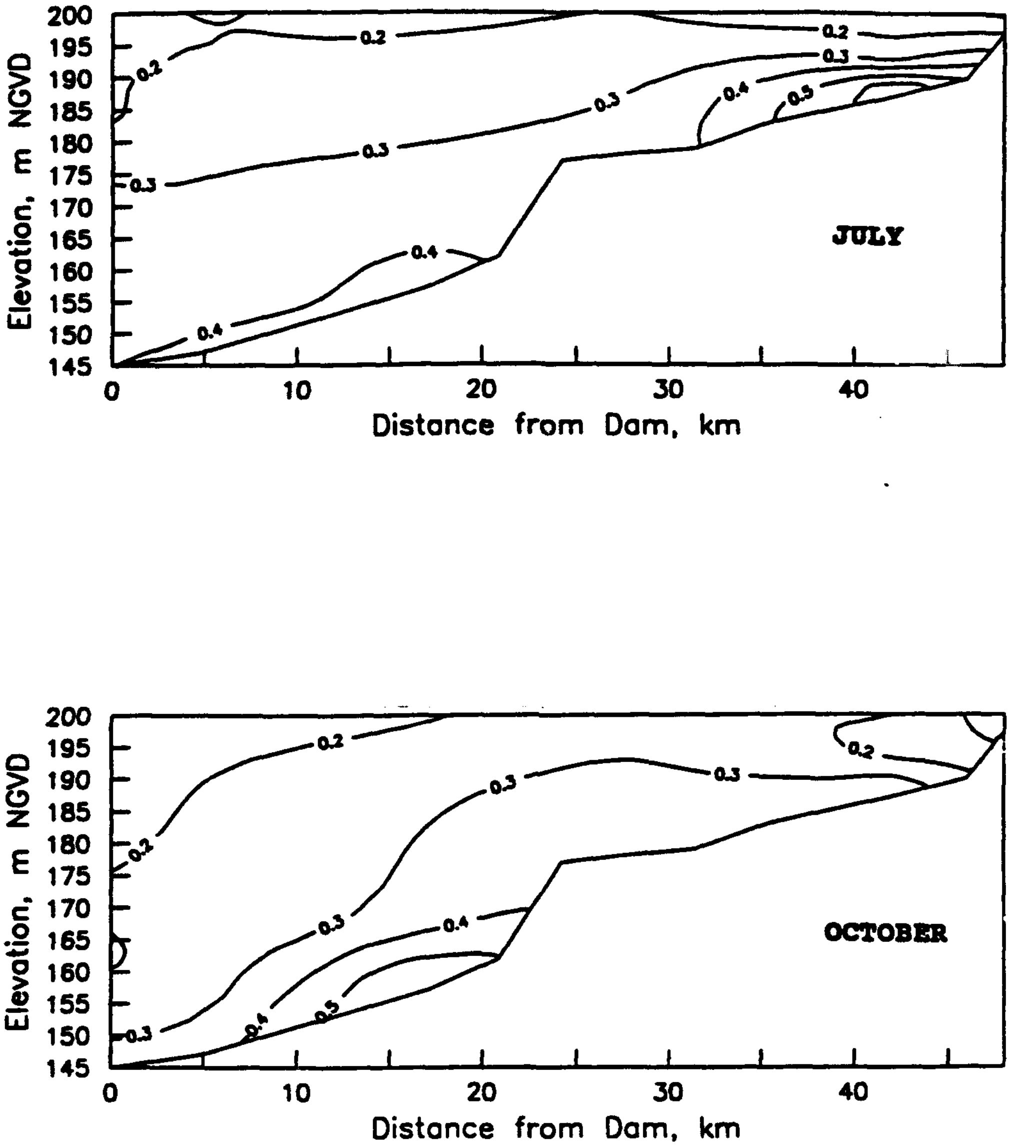


Figure 20. Patterns of spatial distribution of total nitrogen concentrations (mg/l) from Hartwell Dam to upper Seneca River, July and October, 1992

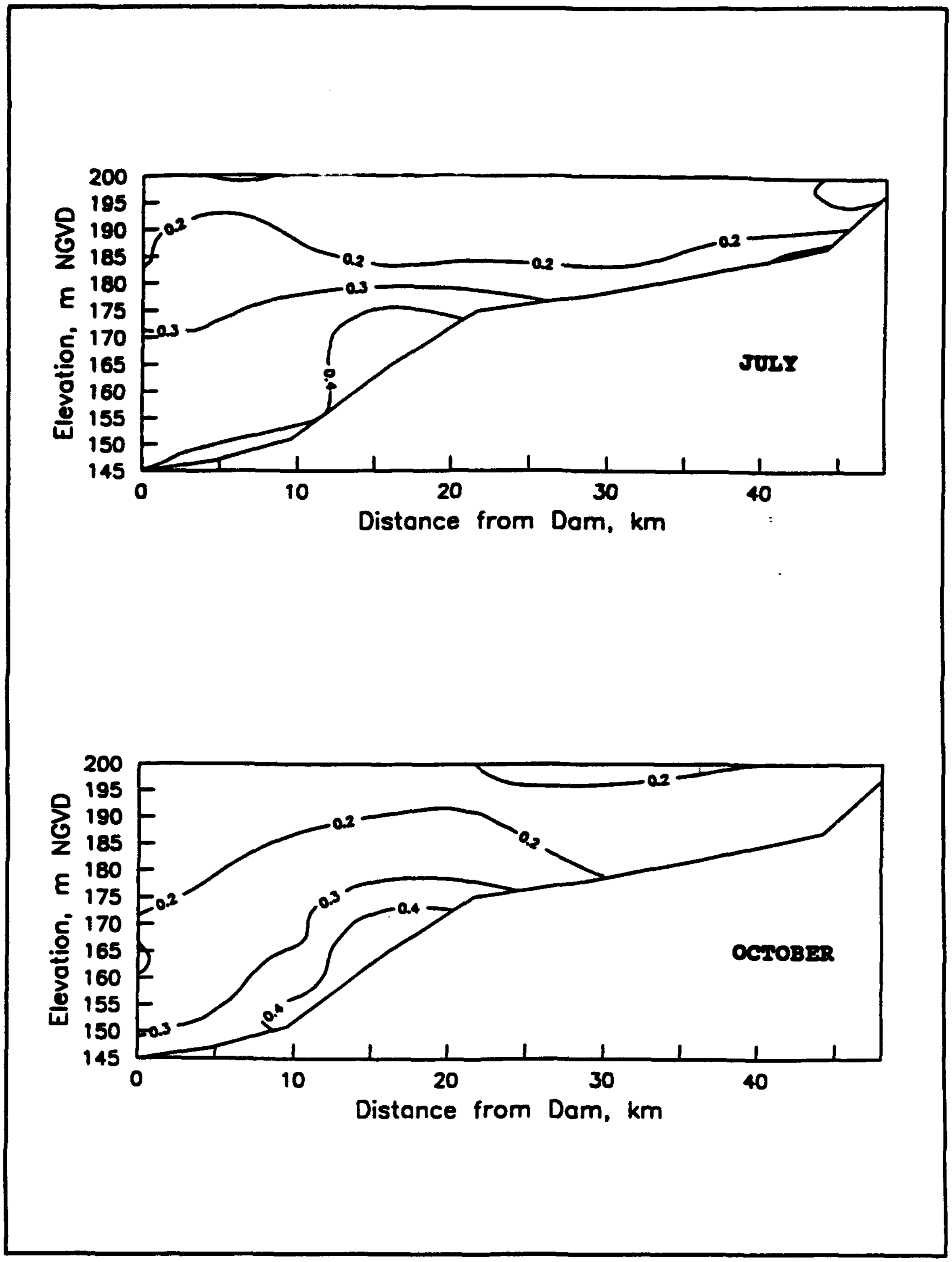


Figure 21. Patterns of spatial distribution of total nitrogen concentrations (mg/l) from Hartwell Dam to upper Tugaloo River, July and October, 1992

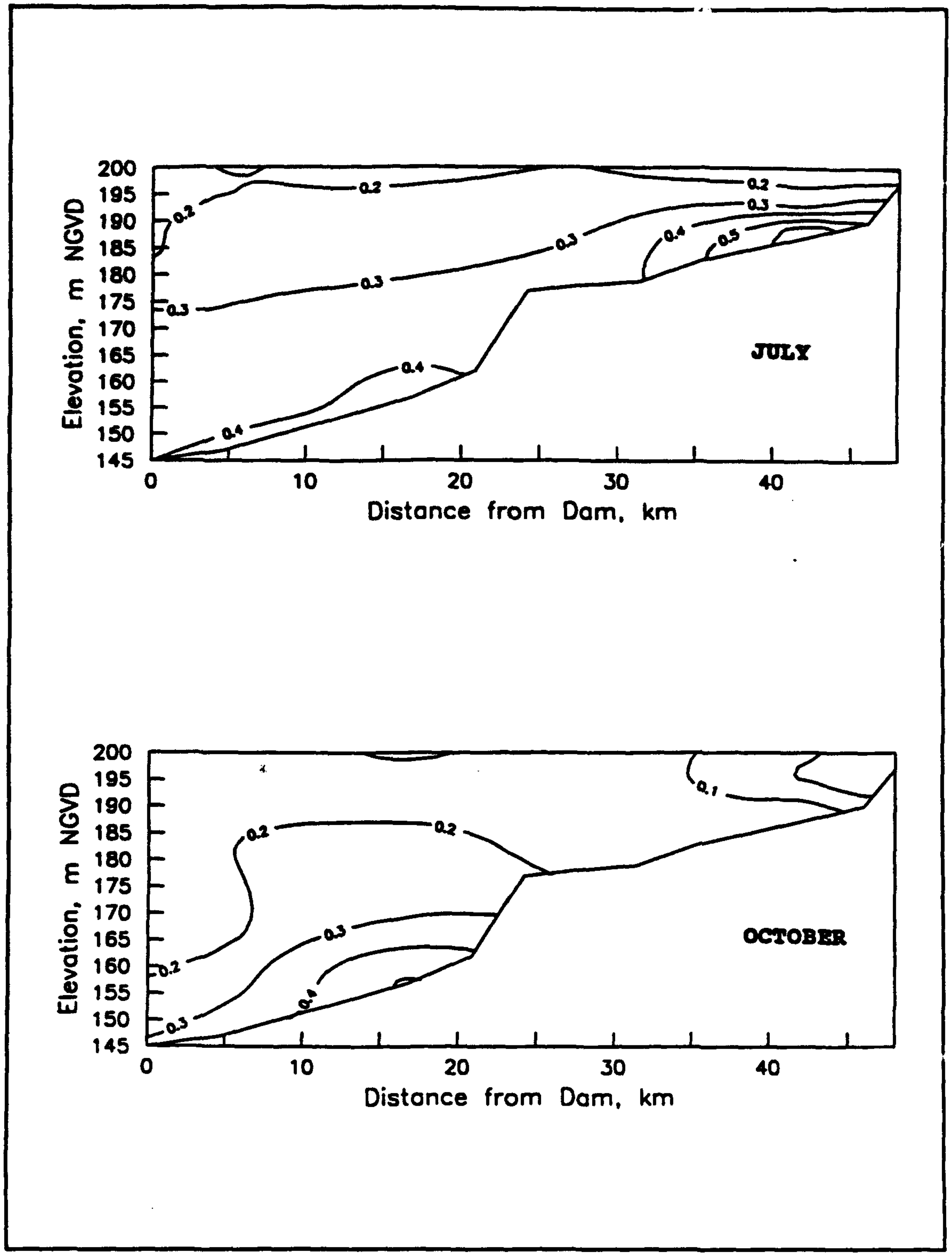


Figure 22. Patterns of spatial distribution of dissolved nitrogen concentrations (mg/l) from Hartwell Dam to upper Seneca River, July and October, 1992

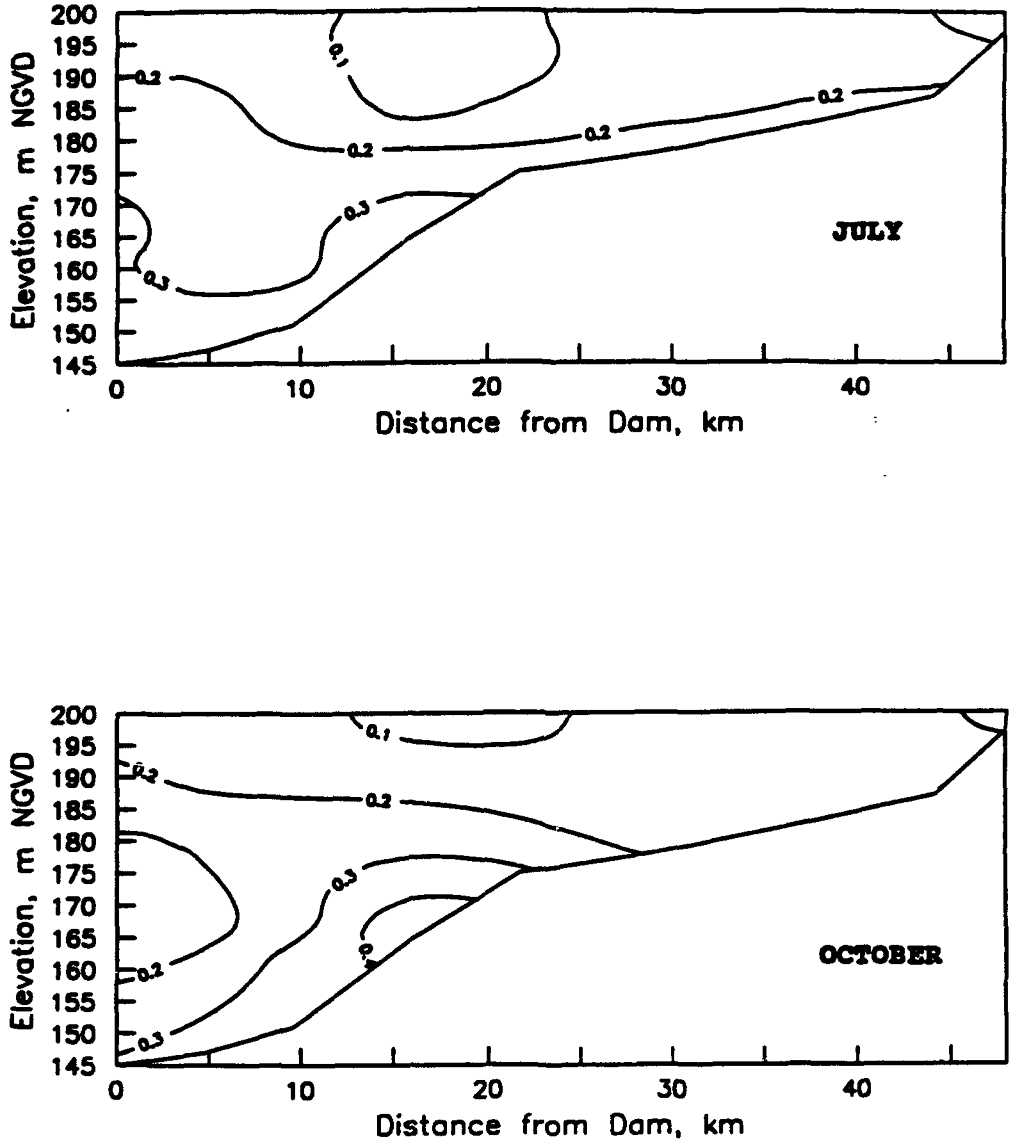
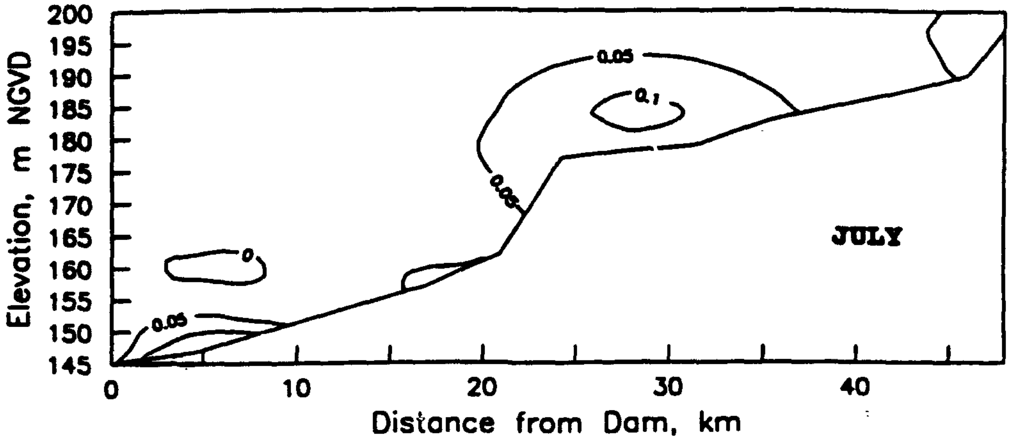


Figure 23. Patterns of spatial distribution of dissolved nitrogen concentrations (mg/l) from Hartwell Dam to upper Tugaloo River, July and October, 1992



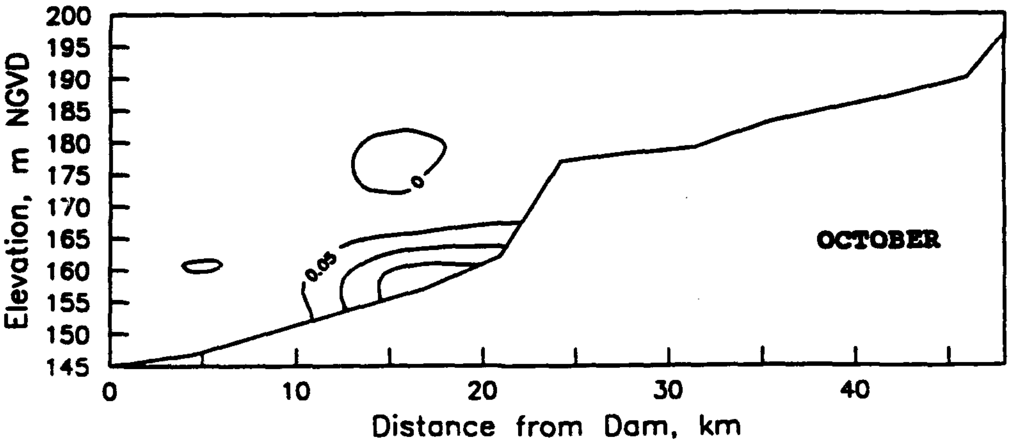


Figure 24. Patterns of spatial distribution of ammonia-nitrogen concentrations (mg/l) from Hartwell Dam to upper Seneca River, July and October, 1992

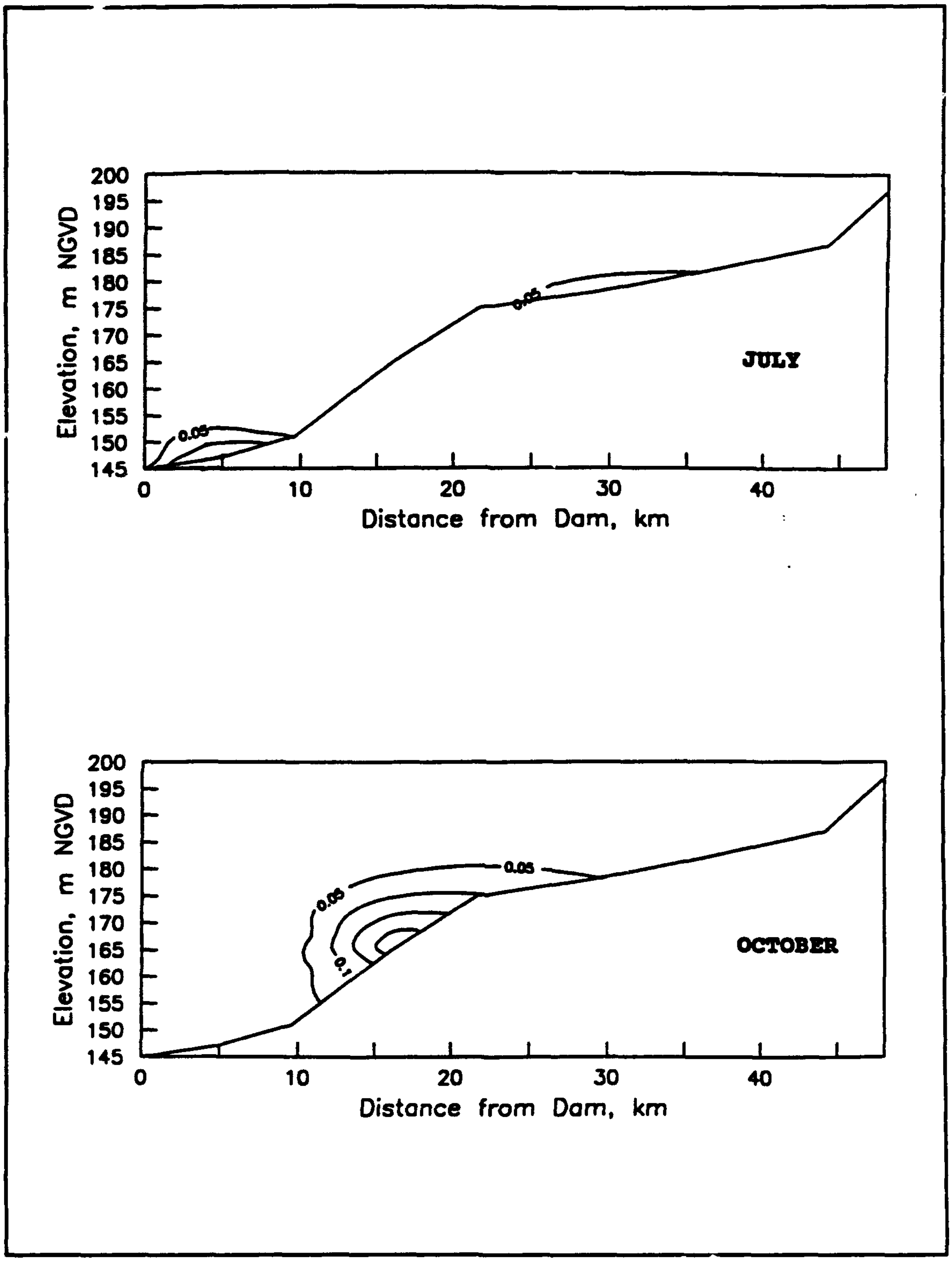


Figure 25. Patterns of spatial distribution of ammonia-nitrogen concentrations (mg/l) from Hartwell Dam to upper Tugaloo River, July and October, 1992

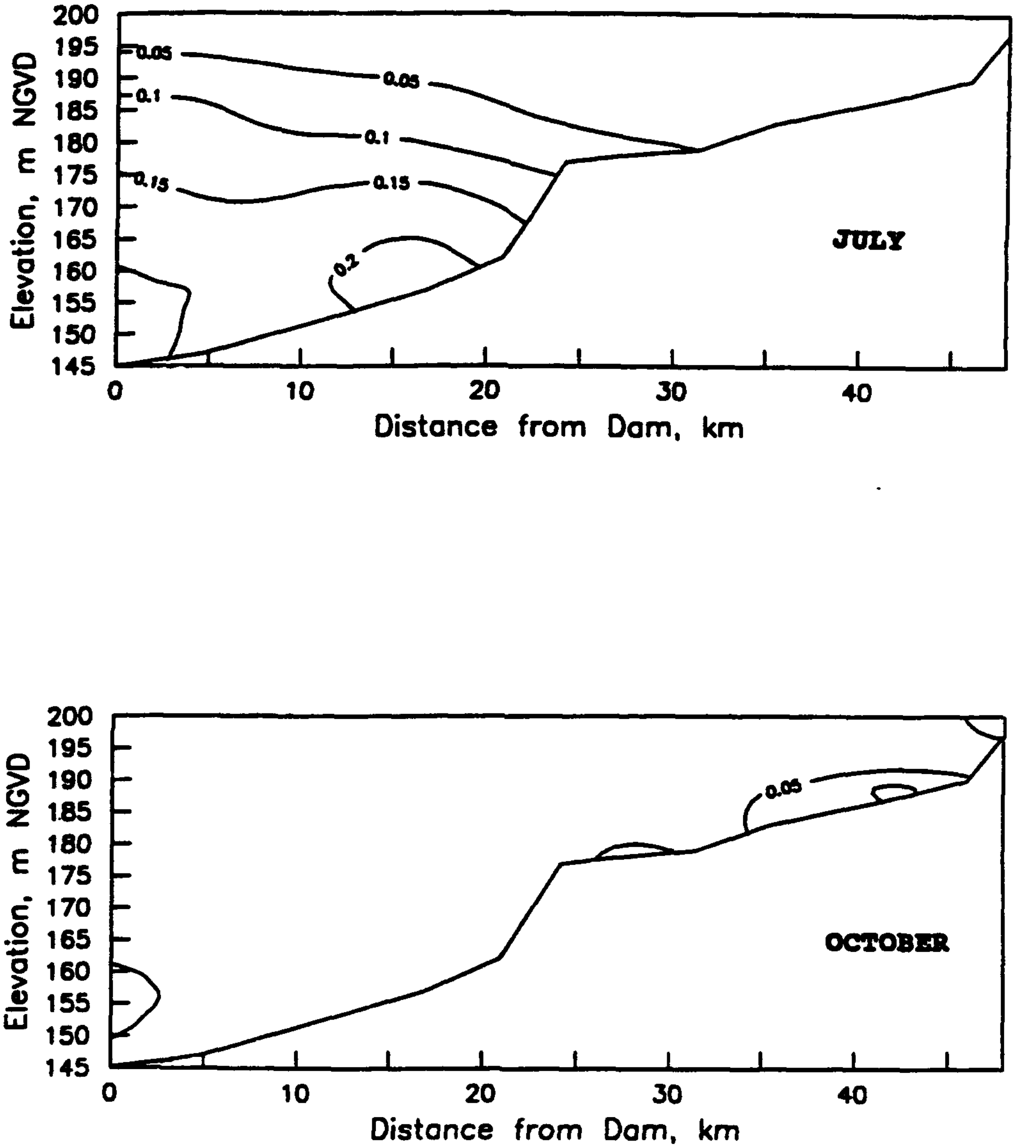


Figure 26. Patterns of spatial distribution of nitrate-nitrogen concentrations (mg/l) from Hartwell Dam to upper Seneca River, July and October, 1992

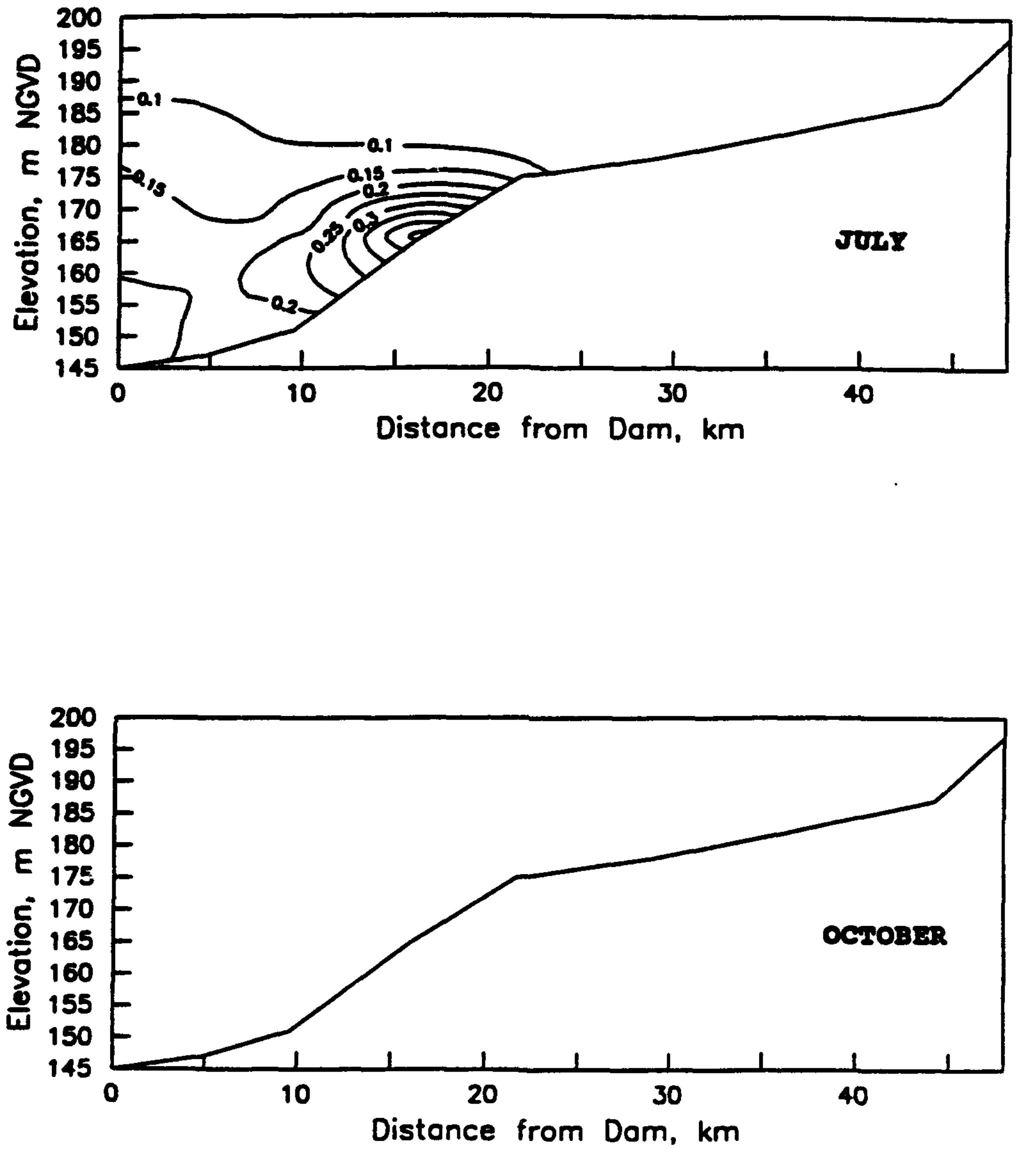


Figure 27. Patterns of spatial distribution of nitrate-nitrogen concentrations (mg/l) from Hartwell Dam to upper Tugaloo River, July and October, 1992

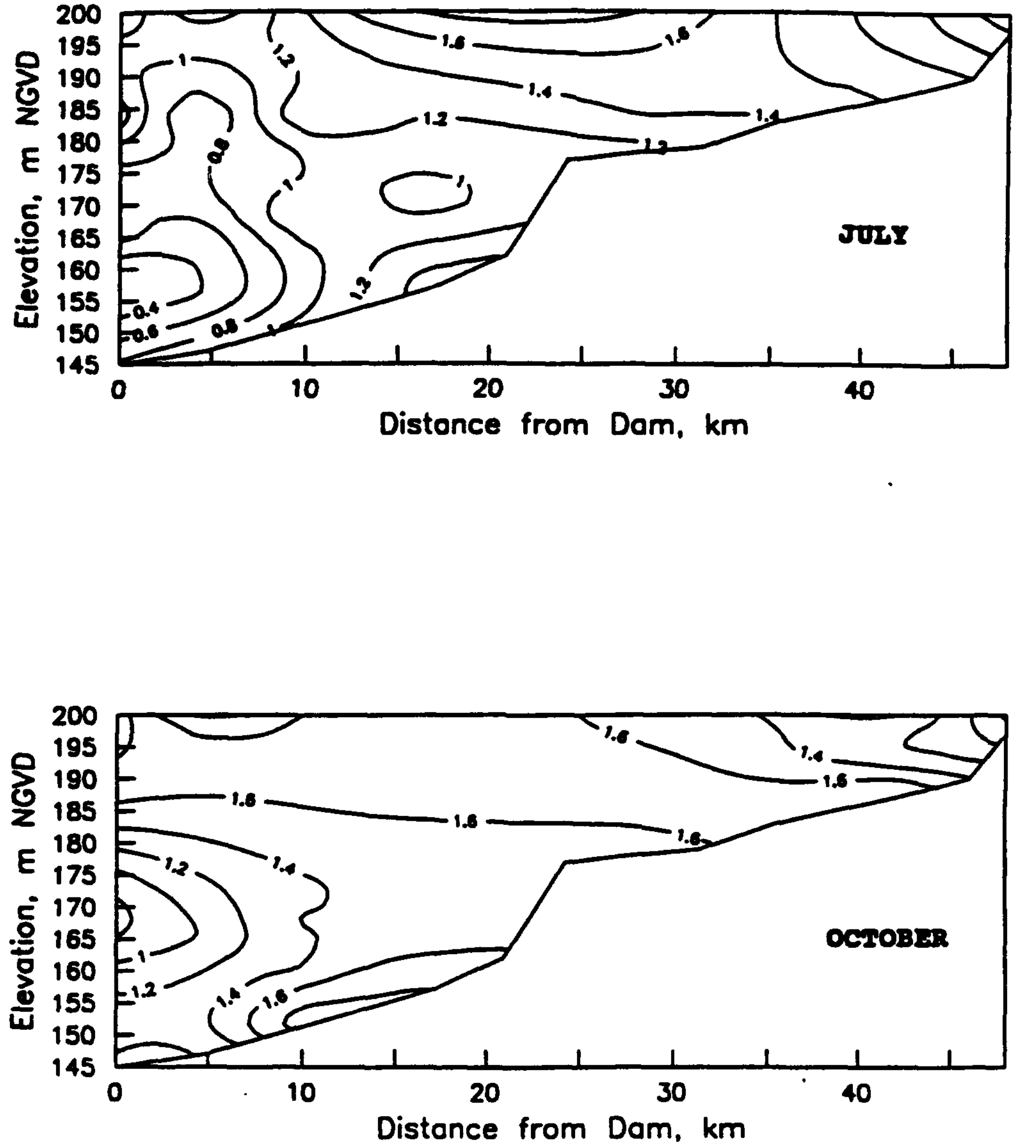


Figure 28. Patterns of spatial distribution of total organic carbon concentrations (mg/l) from Hartwell Dam to upper Seneca River, July and October, 1992

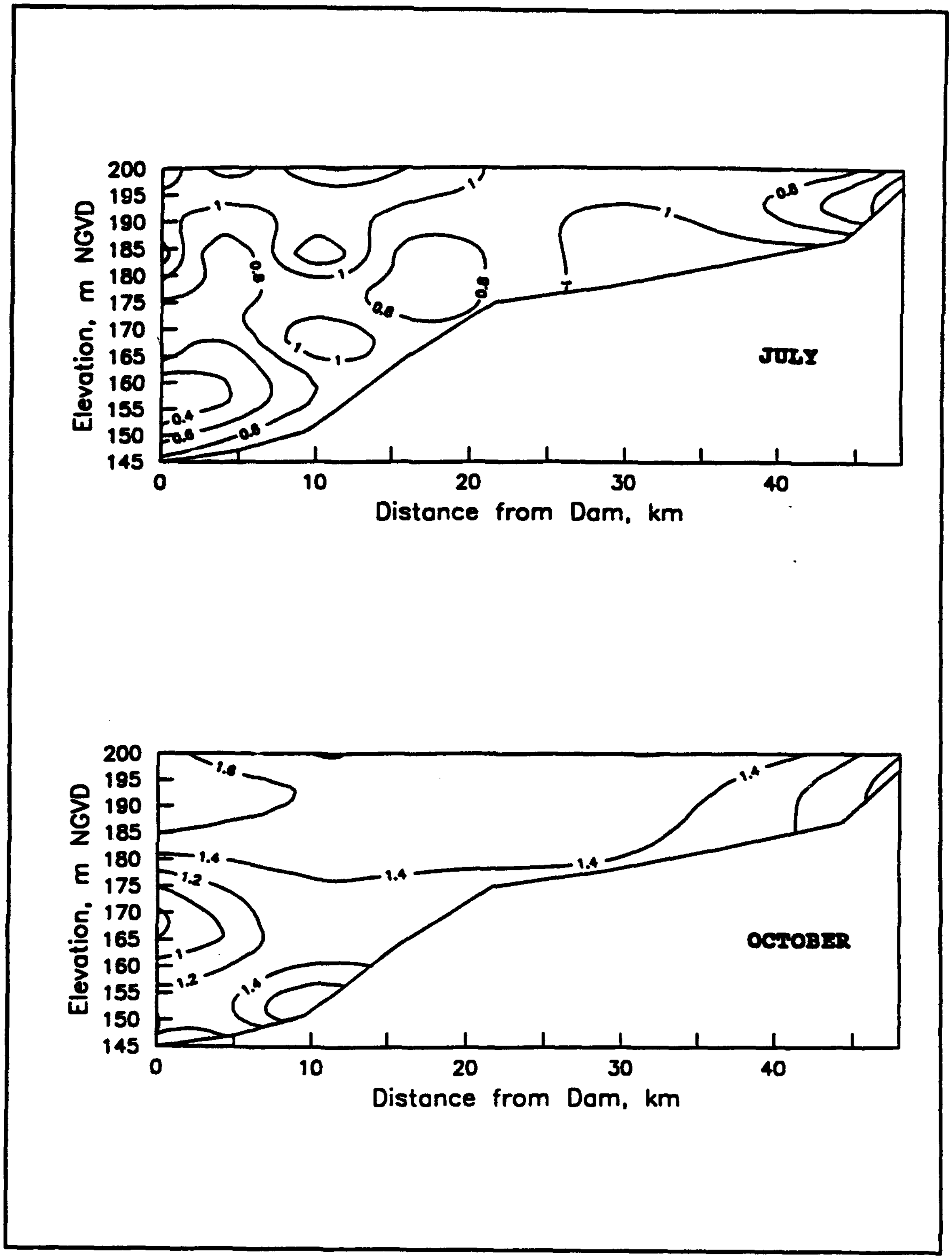


Figure 29. Patterns of spatial distribution of total organic carbon concentrations (mg/l) from Hartwell Dam to upper Tugaloo River, July and October, 1992

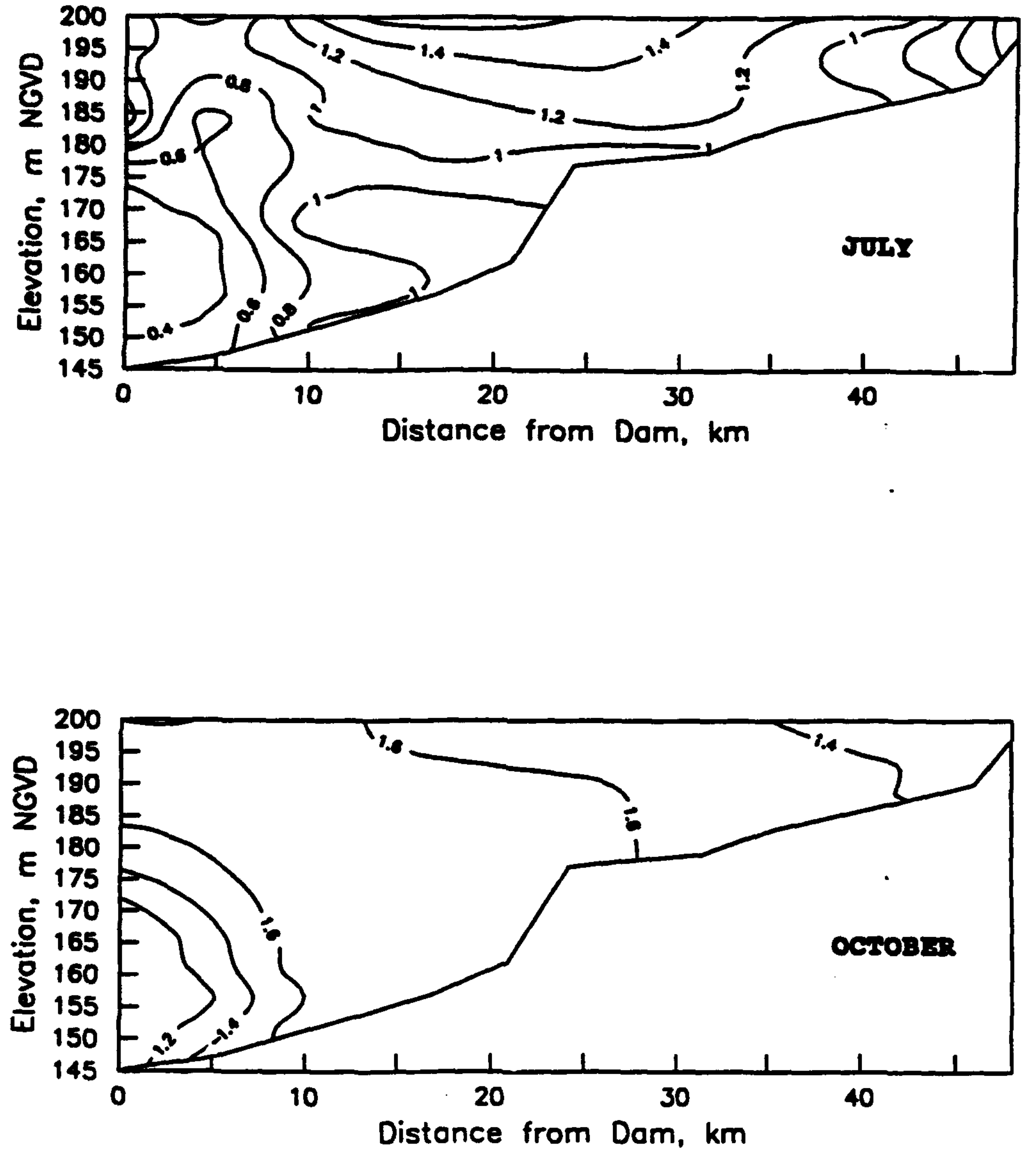


Figure 30. Patterns of spatial distribution of dissolved organic carbon concentrations (mg/l) from Hartwell Dam to upper Seneca River, July and October, 1992

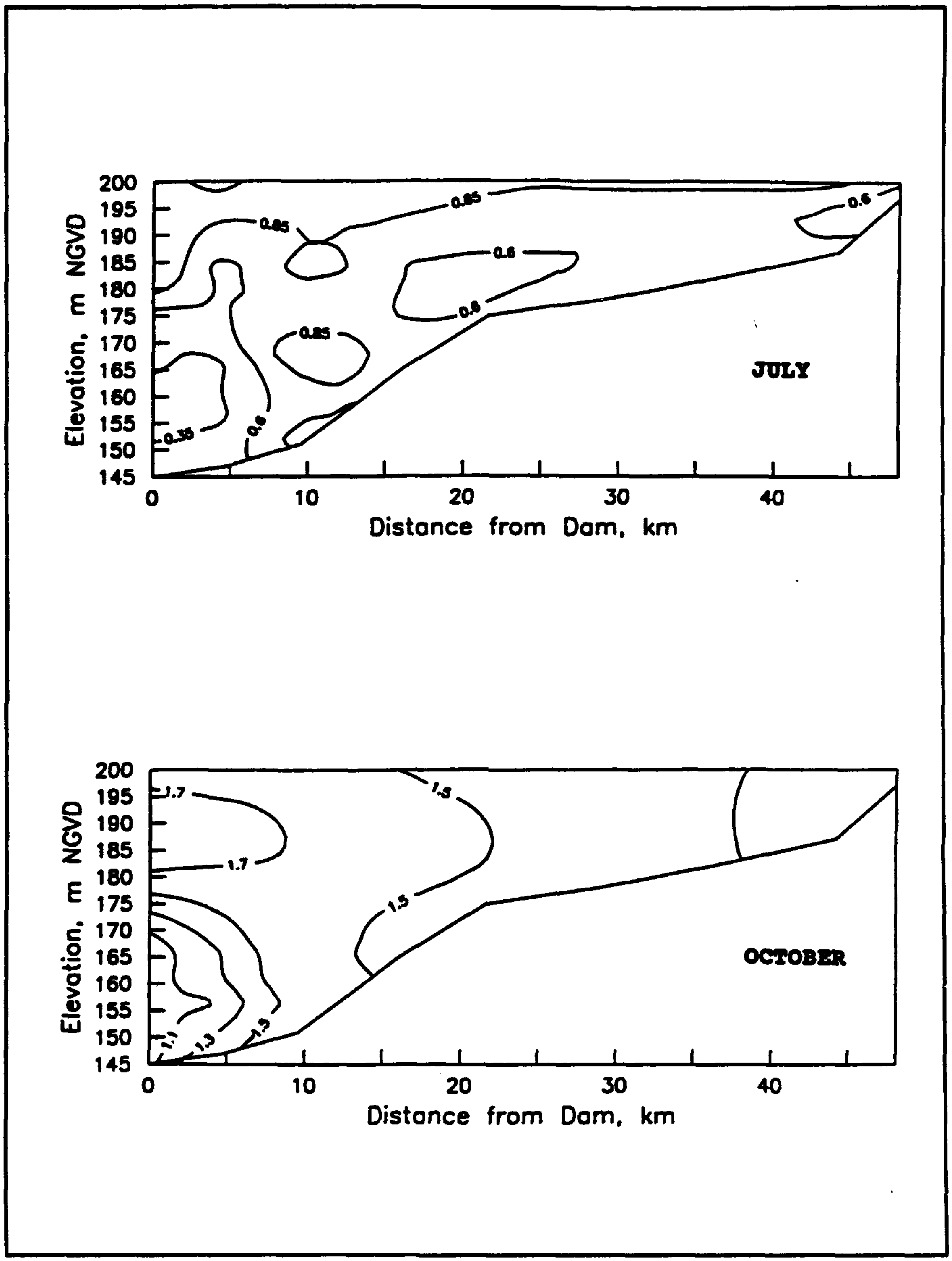


Figure 31. Patterns of spatial distribution of dissolved organic carbon concentrations (mg/l) from Hartwell Dam to upper Tugaloo River, July and October, 1992

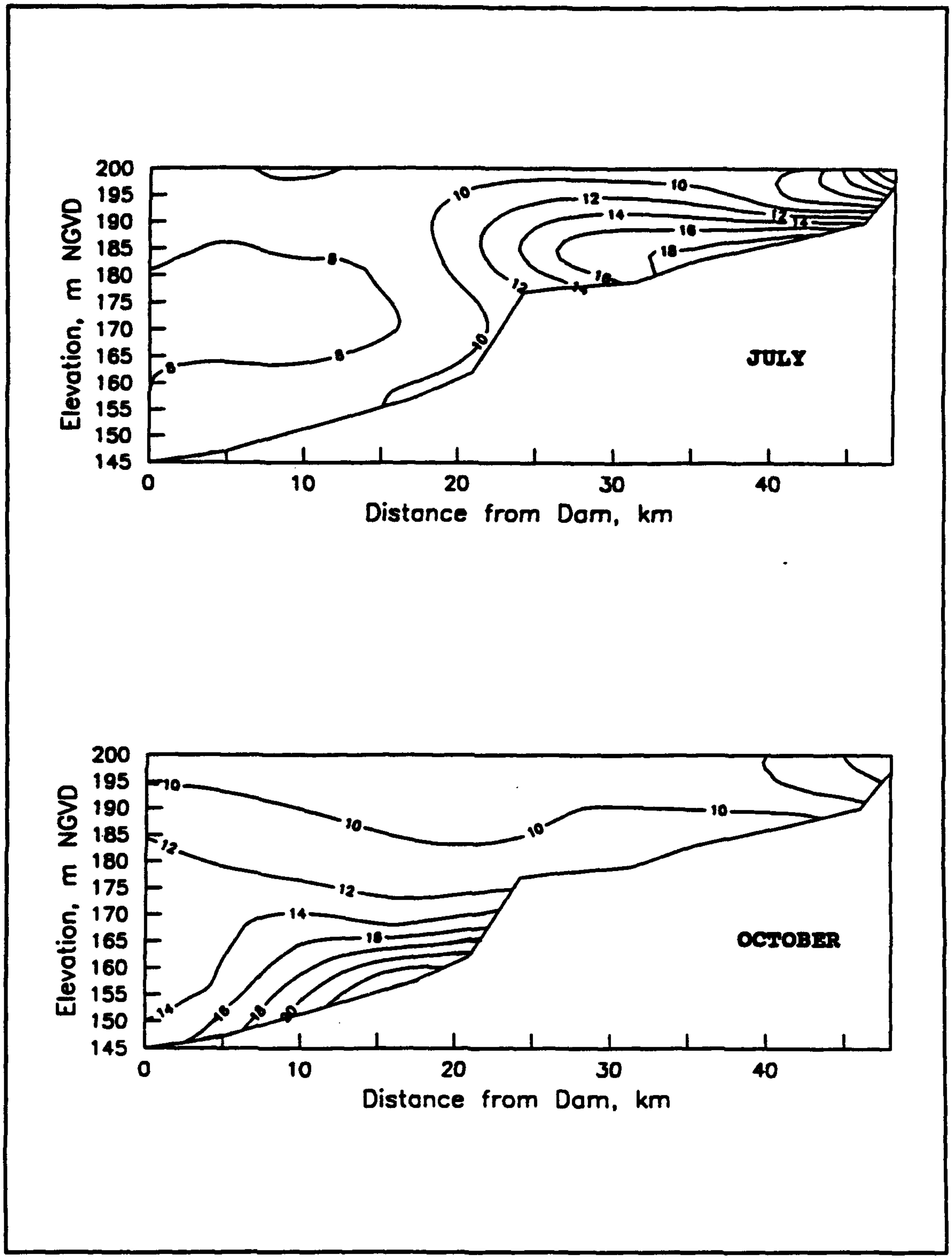


Figure 32. Patterns of spatial distribution of total alkalinity (mg/l) from Hartwell Dam to upper Seneca River, July and October, 1992

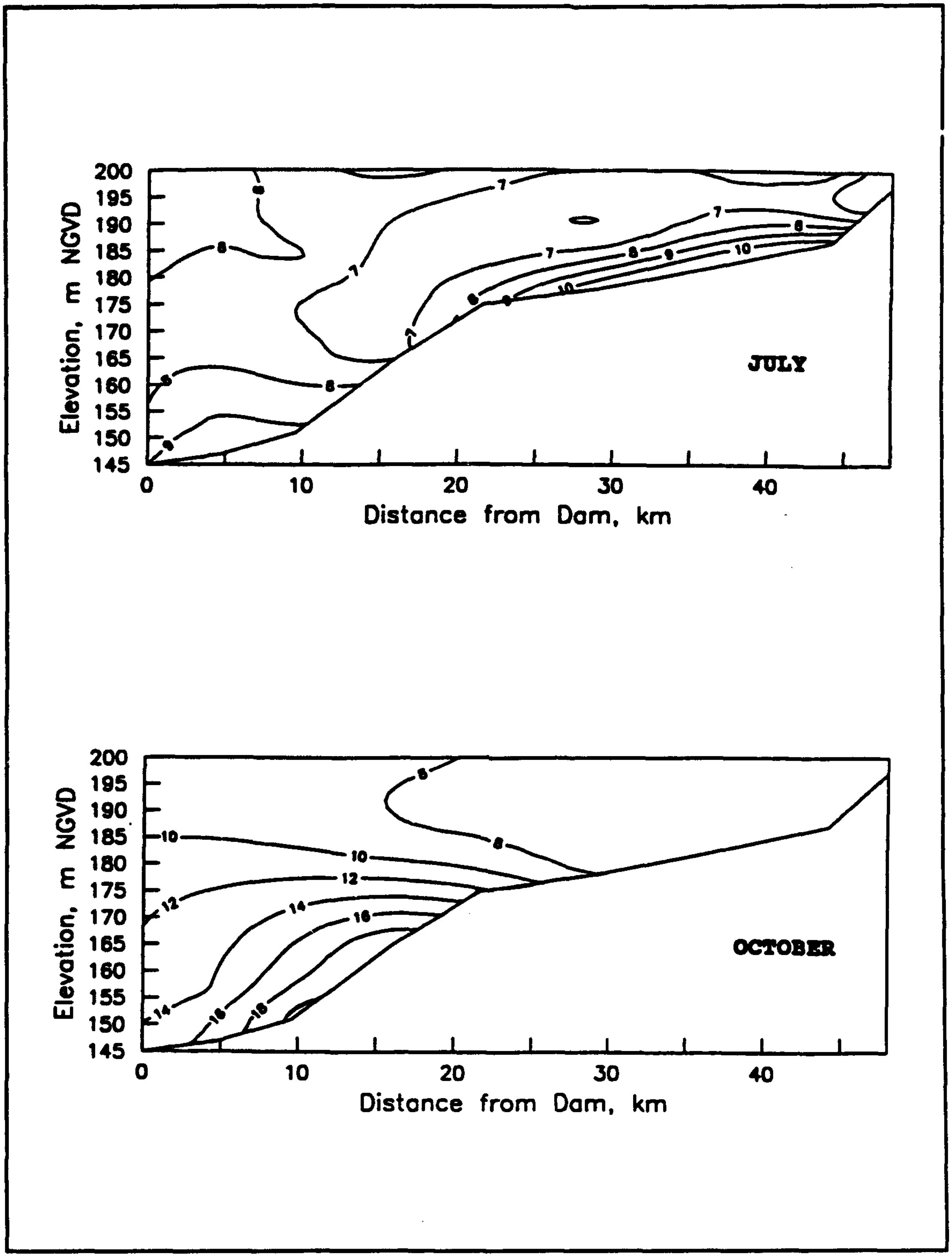


Figure 33. Patterns of spatial distribution of total alkalinity (mg/l) from Hartwell Dam to upper Tugaloo River, July and October, 1992

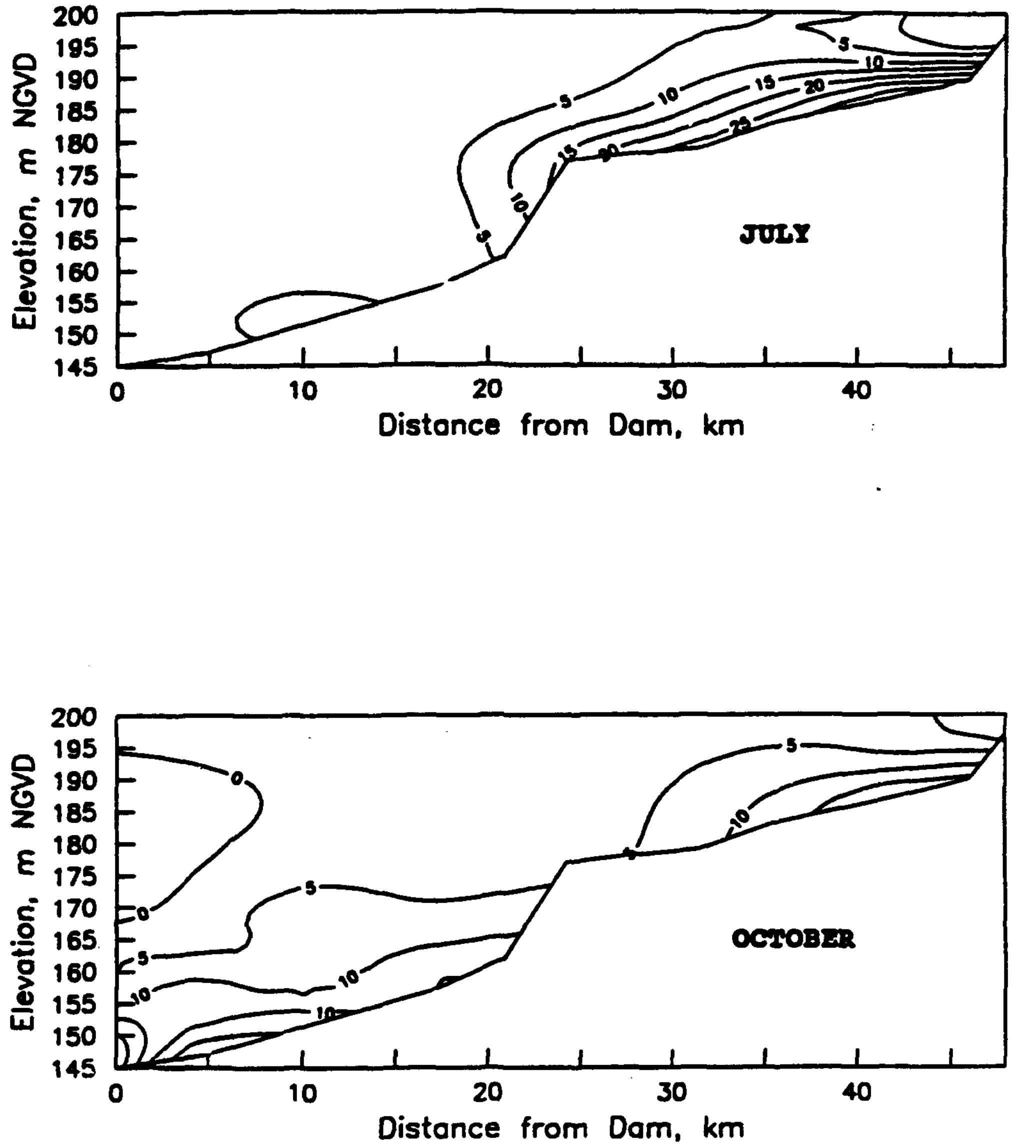


Figure 34. Patterns of spatial distribution of turbidity concentrations (NTU) from Hartwell Dam to upper Seneca River, July and October, 1992

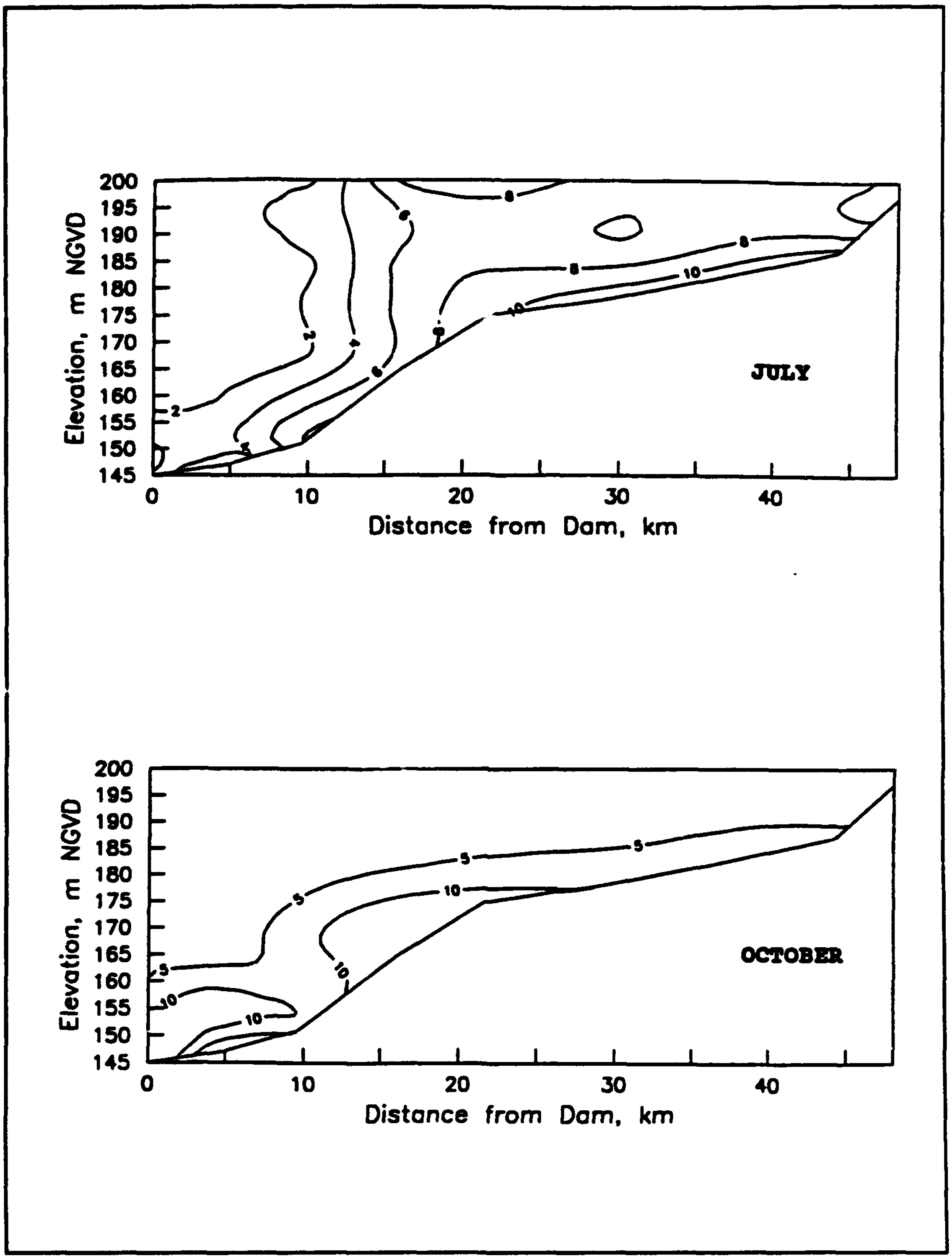


Figure 35. Patterns of spatial distribution of turbidity concentrations (NTU) from Hartwell Dam to upper Tugaloo River, July and October, 1992

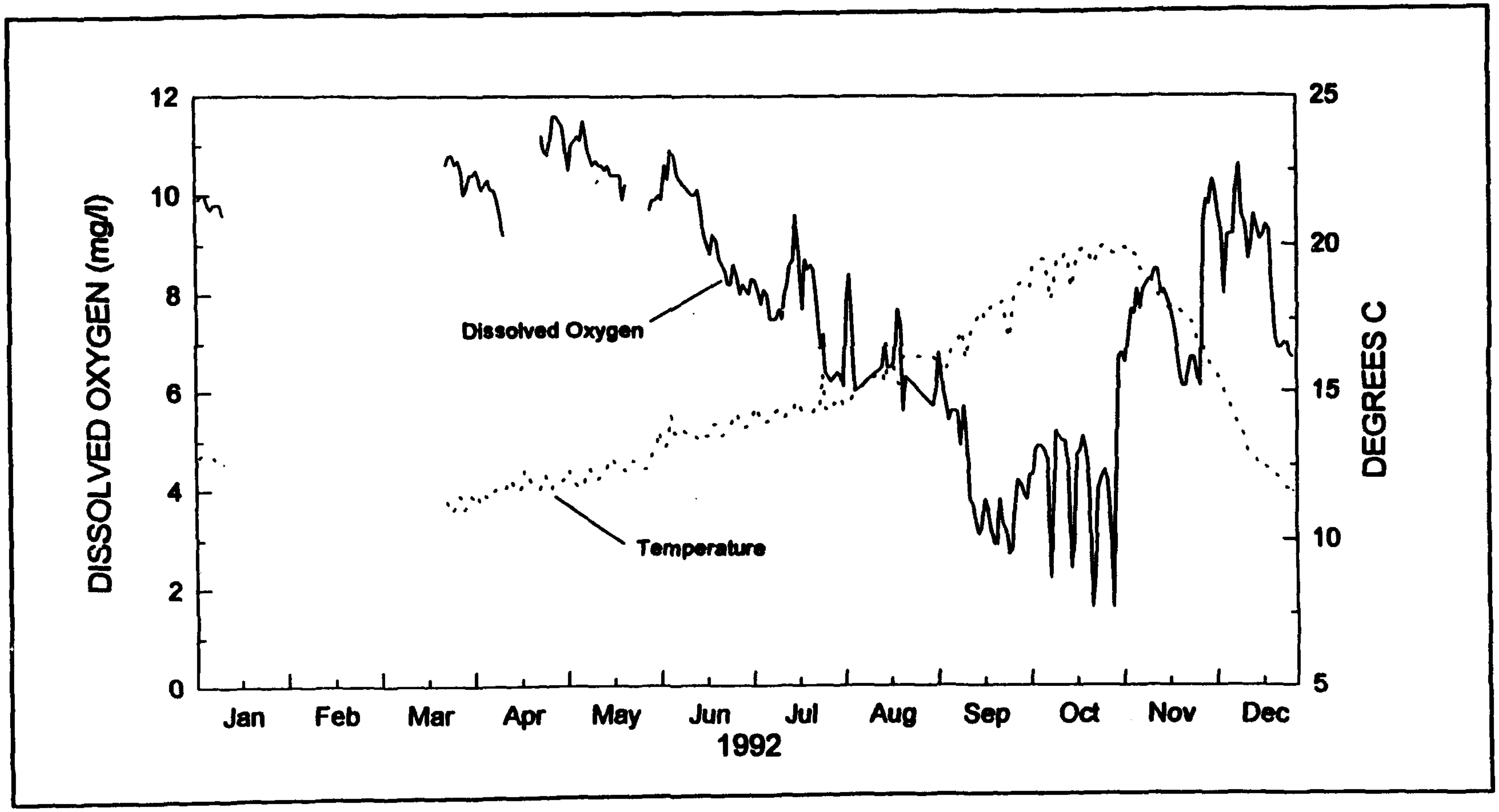


Figure 36. Temporal changes in daily mean temperature and dissolved oxygen concentrations (mg/l) for Hartwell Lake tailwater during 1992

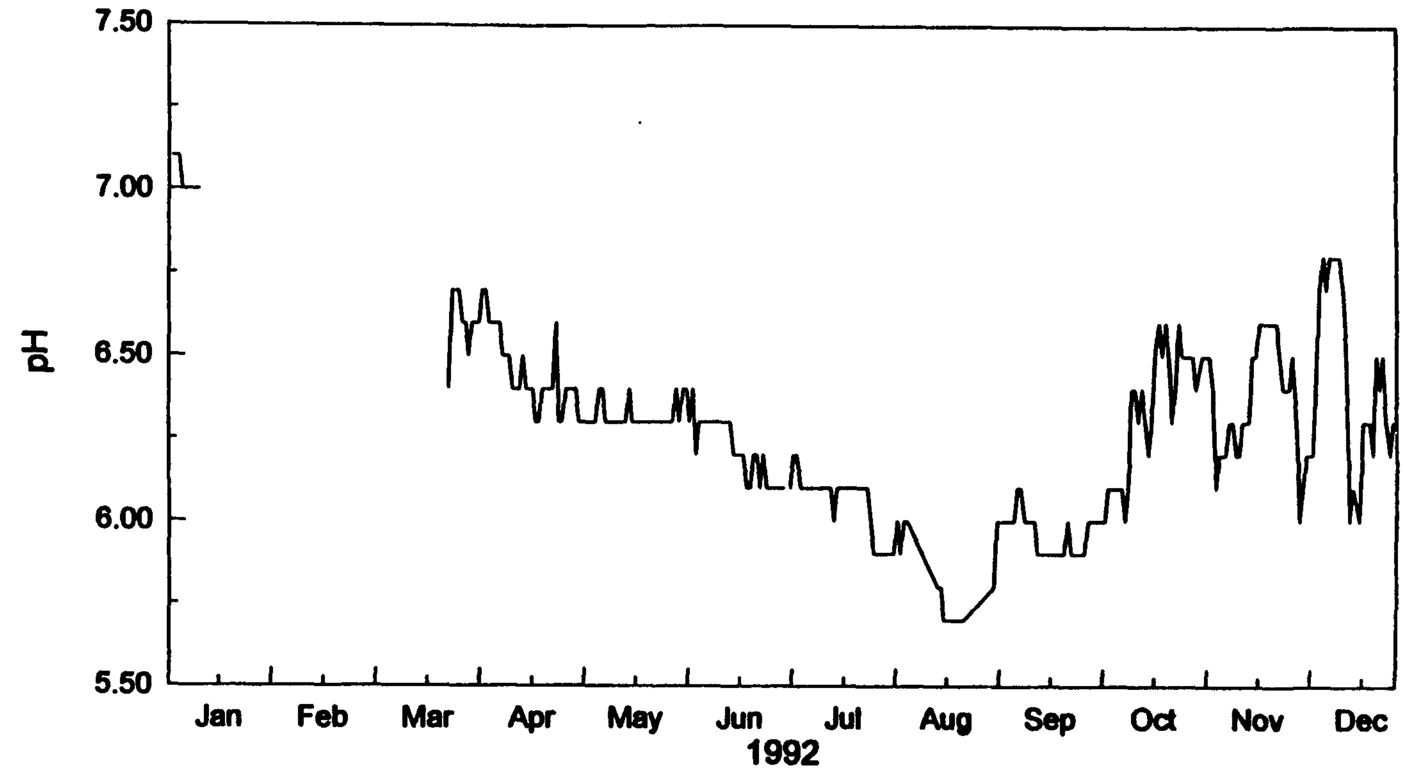


Figure 37. Temporal changes in daily mean pH (pH units) for Hartwell Lake tailwater during 1992

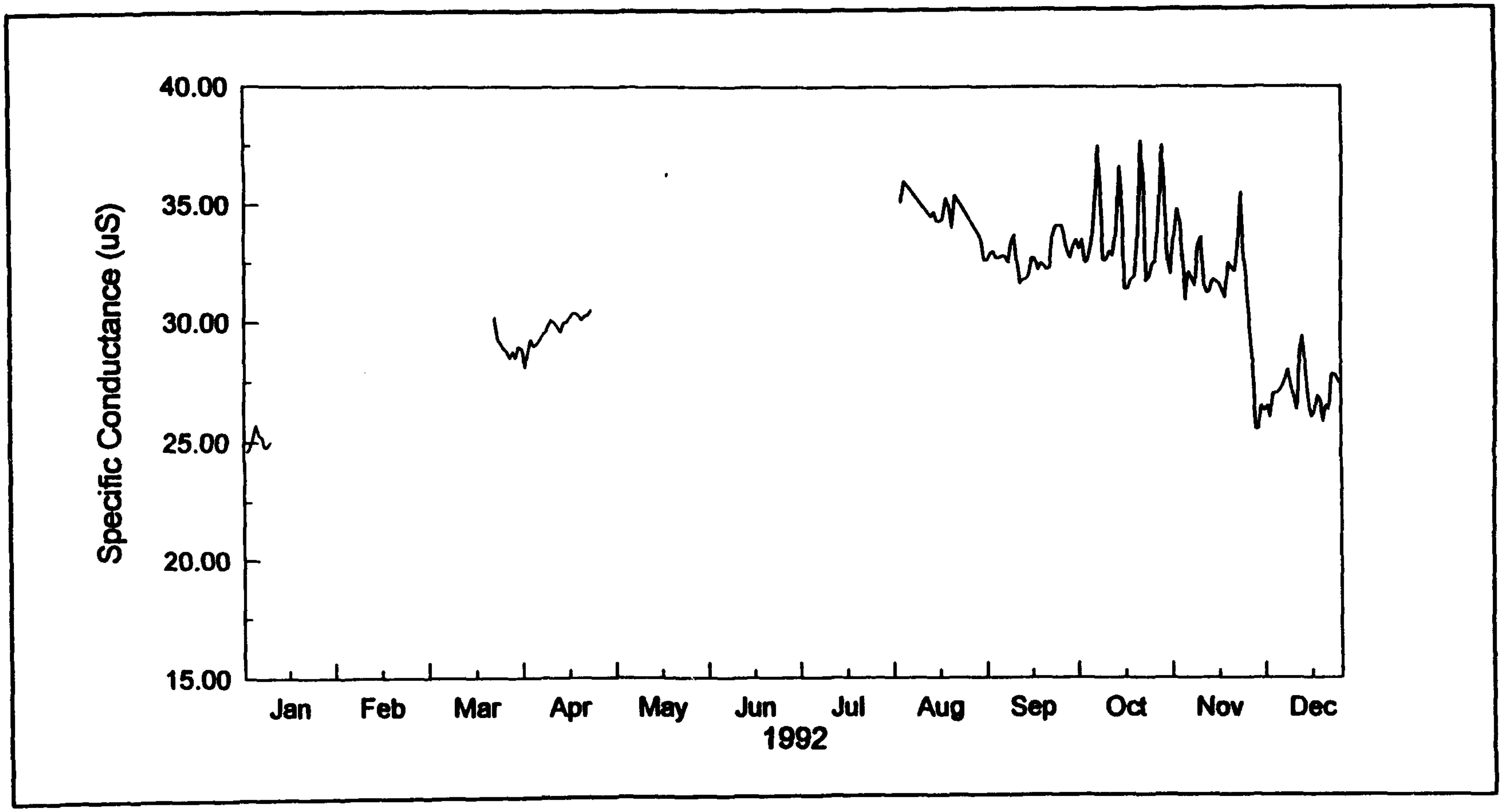


Figure 38. Temporal changes in daily mean specific conductance for Hartwell Lake tailwater during 1992

Table 1
List of Variables

In Situ	Nutrients
Temperature	Total organic carbon
Dissolved oxygen	Dissolved organic carbon
pH	Total phosphorus
Specific conductance	Total soluble phosphorus
	Soluble reactive phosphorus
Physicochemical	Total nitrogen
Turbidity	Total soluble nitrogen
Total alkalinity	Ammonium-nitrogen
	Nitrate-nitrite nitrogen

Table 2
Summary of Hartwell Lake Epilimnetic In Situ and Water Chemistry Data for 22-23 July 1992

Variable[1]	Mean[2]	Minimum	Maximum	n[3]
Dissolved Oxygen	7.3	2.0	9.2	80
Temperature, °C	28.2	24.5	30.7	80
Specific Conductance, µS	28.6	20.0	36.0	65
pH, pH units	7.0	6.2	7.6	65
Turbidity NTU's	2.4	1.4	4.8	7
Suspended Solids	.	.	.	0
Total Alkalinity	7.9	6.6	8.8	11
Total Organic Carbon	1.2	0.5	1.8	11
Dissolved Organic Carbon	1.1	0.7	1.7	10
Total Phosphorus	0.009	0.006	0.014	11
Total Soluble Phosphorus	0.005	0.005	0.005	11
Soluble Reactive Phosphorus	0.005	0.005	0.005	11
Total Nitrogen	0.10	0.22	0.17	11
Dissolved Nitrogen	0.05	0.17	0.12	11
Ammonia Nitrogen	0.021	0.020	0.030	11
Nitrate Nitrite Nitrogen	0.020	0.020	0.020	11

[1] Units are mg/l except for noted variables.
[2] Means are calculated using detection limit values.
[3] n = Number of observations on which calculations are based.

Table 3
Summary of Hartwell Lake Hypolimnetic In Situ and Water Chemistry Data for 22-23 July 1992

Variable[1]	Mean[2]	Minimum	Maximum	n[3]
Dissolved Oxygen	3.8	0.1	9.2	202
Temperature, °C	15.6	11.1	25.3	202
Specific Conductance, µS	34.3	21.0	77.0	145
pH, pH units	6.5	5.9	7.3	145
Turbidity, NTU's	5.7	1.0	31.0	17
Suspended Solids	.	.	.	0
Total Alkalinity	9.5	6.0	18.1	23
Total Organic Carbon	1.0	0.3	1.5	23
Dissolved Organic Carbon	0.8	0.3	1.3	22
Total Phosphorus	0.011	0.005	0.075	23
Total Soluble Phosphorus	0.005	0.005	0.005	23
Soluble Reactive Phosphorus	0.005	0.005	0.005	23
Total Nitrogen	0.34	0.150	0.690	23
Dissolved Nitrogen	0.28	0.080	0.580	23
Ammonia Nitrogen	0.038	0.020	0.140	23
Nitrate Nitrite Nitrogen	0.141	0.020	0.470	23

1 Units are mg/l except for noted variables.
2 Means are calculated using detection limit values.
3 n = Number of observations on which calculations are based.

Table 4
Summary of Hartwell Lake Epilimnetic In Situ and Water Chemistry Data for 21 October 1992

Variable[1]	Mean[2]	Minimum	Maximum	n[3]
Dissolved Oxygen	7.1	4.7	8.4	119
Temperature, °C	20.0	18.7	20.9	119
Specific Conductance, µS	43.5	36.0	56.0	119
pH, pH units	6.4	6.1	6.5	119
Turbidity, NTU's	4.5	2.1	18.0	18
Total Alkalinity	8.4	6.6	11.2	18
Total Organic Carbon	1.5	1.1	1.9	18
Dissolved Organic Carbon	1.4	1.2	1.7	18
Total Phosphorus	0.020	0.012	0.050	18
Total Soluble Phosphorus	0.011	0.008	0.014	18
Soluble Reactive Phosphorus	0.005	0.005	0.007	18
Total Nitrogen	0.22	0.16	0.39	18
Dissolved Nitrogen	0.13	0.02	0.22	18
Ammonia Nitrogen	0.02	0.02	0.04	18
Nitrate Nitrite Nitrogen	0.03	0.02	0.13	18

1 Units are mg/l except for noted variables.
2 Means are calculated using detection limit values.
3 n = Number of observations on which calculations are based.

Table 5
Summary of Hartwell Lake Hypolimnetic In Situ and Water Chemistry Data for 21 October 1992

Variable[1]	Mean[2]	Minimum	Maximum	n[3]
Dissolved Oxygen	1.5	0.1	7.4	50
Temperature, °C	16.8	12.9	20.0	50
Specific Conductance, µS	57.1	40.0	89.0	50
pH, pH units	6.1	5.9	6.5	50
Turbidity, NTU's	9.6	2.3	24.0	12
Total Alkalinity	16.1	12.3	23.9	12
Total Organic Carbon	1.3	0.9	1.9	12
Dissolved Organic Carbon	1.4	1.0	1.7	12
Total Phosphorus	0.014	0.010	0.024	12
Total Soluble Phosphorus	0.009	0.006	0.014	12
Soluble Reactive Phosphorus	0.005	0.005	0.005	12
Total Nitrogen	0.35	0.19	0.61	12
Dissolved Nitrogen	0.31	0.15	0.52	12
Ammonia Nitrogen	0.06	0.02	0.24	12
Nitrate Nitrite Nitrogen	0.03	0.02	0.09	12

[1] Units are mg/l except for noted variables.
[2] Means are calculated using detection limit values.
[3] n = Number of observations on which calculations are based.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
October 1993

3. REPORT TYPE AND DATES COVERED
Final report

4. TITLE AND SUBTITLE
Water Quality Studies: Hartwell Lake 1992 Summary Report

5. FUNDING NUMBERS

6. AUTHOR(S)
Cynthia J. Huffstetler, Joe H. Carroll, William E. Jabour

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
AScI Corporation, McClean, VA;
U.S. Army Engineer Waterways Experiment Station
Environmental Laboratory
3909 Halls Ferry Road, Vicksburg, MS 39180-6199

8. PERFORMING ORGANIZATION REPORT NUMBER
Miscellaneous Paper EL-93-

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Engineer District, Savannah
Savannah, GA 31402-0889

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This report documents the results of comprehensive water quality studies performed in Hartwell Lake (HW) during the period January through December 1992. Presented in this report are summaries and comparisons of water quality conditions observed during monthly in situ sampling trips and biannual chemical sampling trips within the main stem and two major embayments on Hartwell Lake.

The onset of thermal stratification began in Hartwell Lake during early March and by mid-April, extensive stratification was present from the headwaters of each major embayment to the forebay. Anoxic conditions were observed in the middle reaches of the Seneca and Tugaloo Rivers during the July sampling trip. The greatest concentrations of chemical constituents within the two embayments were also recorded during the mid-July sampling period. By mid-October, stratification in the upstream regions had diminished due to normal seasonal cooling, but persisted in the deeper waters of the forebay until early November.

Intensive physicochemical sampling during July, revealed increased concentrations of specific nutrients and organic carbons normally associated with anoxic conditions in the bottom waters of an embayment.

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14. SUBJECT TERMS

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED		

REPORT DOCUMENTATION PAGE

Form Approved
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8. PERFORMING ORGANIZATION REPORT NUMBER
Miscellaneous Paper EL-93-21

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Engineer District, Savannah
Savannah, GA 31402-0889

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(Continued)

14. SUBJECT TERMS

Dissolved oxygen	Savannah River
Lake Hartwell	Water quality
Limnology	

15. NUMBER OF PAGES
57

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT
UNCLASSIFIED

18. SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

19. SECURITY CLASSIFICATION OF ABSTRACT

20. LIMITATION OF ABSTRACT

13. (Concluded).

Concentrations of those nutrients within the middle reaches of the Seneca River embayment were consistently greater than those concentrations observed in the Tugaloo River embayment. A subsequent sampling trip in October indicated that anoxic conditions within the two primary embayments no longer existed. Anoxia did, however, persist in the deeper, near-dam stations and was confirmed by the presence of greater concentrations of chemical variables.

Continuous data for temperature, dissolved oxygen, pH, and specific conductivity were collected using a Schneider RM-25 monitor in the tailrace below Hartwell Dam. These data reflected seasonal variability and were indicative of water quality conditions in the forebay of Hartwell Lake.

Hartwell Dam outflows were fairly consistent in response to precipitation and inflow levels early in the year, but nearly doubled September through November and were more than four times greater in December, this due to a tremendous increase in precipitation during November. Inflows were also much higher in those months due to greater than average rainfall during August through December, nearly double the inflows observed in 1991.